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—OF THE—

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A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries

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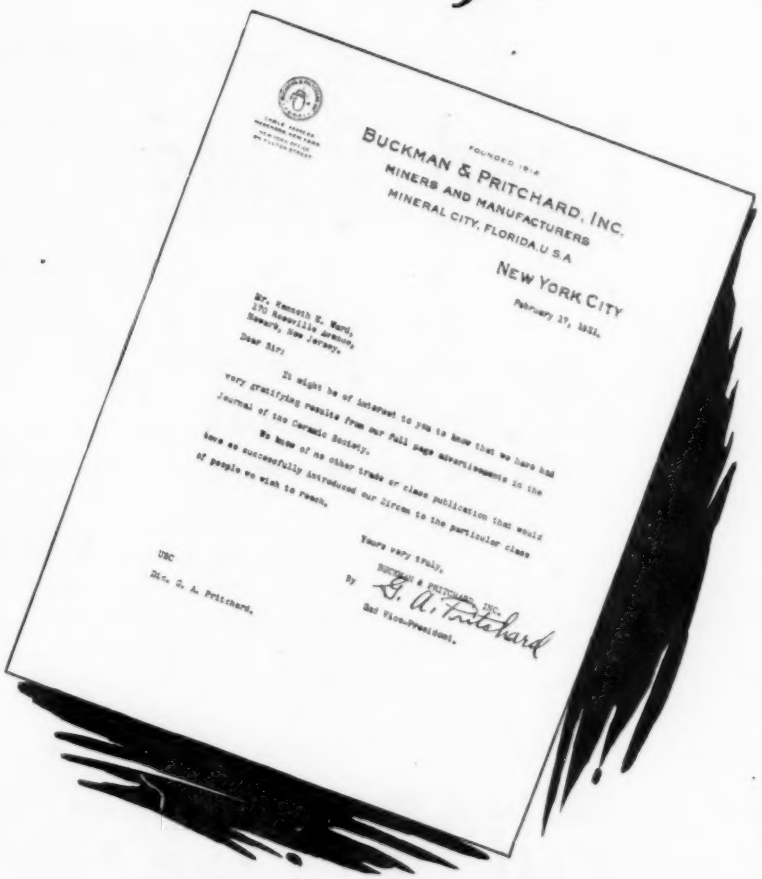

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JOURNAL
OF THE
AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Editor: E. W. WASHBURN; **Associate Editors:** L. E. BARRINGER, A. V. BLEININGER, R. L. CLARE, E. P. POSTE, H. RIES, F. H. RHEAD, R. B. SOSMAN, R. T. STULL, E. W. TILLOTSON

Vol. 4 **September, 1921** **No. 9**

EDITORIAL

RESEARCH AND A PROTECTIVE TARIFF

There has recently come to the editor's desk a set of pamphlets issued by the United States Tariff Commission entitled "Tariff Information Surveys." The material contained in these pamphlets has been collected for the use of the committees of Congress in the preparation of tariff schedules. The information given is intended to represent a condensed and up-to-date account of the conditions in the various industries, as regards the nature and supplies of raw materials, manufacturing processes, labor, capital, transportation, domestic and foreign markets, costs, imports and exports, competition, tariff history, duties in foreign countries, and in general, all information which might have a bearing upon tariff schedules.

In the pamphlet dealing with clays and earths, occurs the following statement:

"It is doubtful if domestic kaolin can entirely replace the imported product, unless the quality of the domestic material improves, either through the discovery of new high-grade deposits or improved systems of purifying and standardizing the product now being mined. Increased duties might not result in immediate reduction of imports but would undoubtedly stimulate research work on the part of domestic consumers to the end that, eventually, a larger percentage of domestic kaolin would be used in the pottery and paper trades."

This statement raises a subject which we do not recall ever having seen discussed, namely the possible effects of a protective tariff upon the development of scientific research. The point of view adopted in the statement quoted, could not be safely generalized without some qualification. In some industries the creation of a protective duty, especially one which was restricted to a definite and not too long period of years, might very likely serve as a powerful stimulant to scientific research. This would most probably be the result in an industry where the value of scientific research was understood and appreciated.

On the other hand, it seems equally, or more, probable that the opposite policy might be even more effective. If the industries of the country were given to understand that no tariff protection would be given to any industry which refused or neglected to maintain either individual or coöperative research laboratories, adequately staffed and equipped for the prosecution of scientific research in the direction of lower costs, new and improved products, safer and better working conditions, increased knowledge of all factors entering into the industry,—in a word *continuous progress*, it is at least probable that the stimulating effect upon the research work of the country would be far greater. The second policy would have the further advantage that those industries which took advantage of it in order to secure tariff protection, would eventually find themselves in a position where such protection was no longer required. We venture to express the hope that at future Congressional hearings on tariff schedules, we may find the chairman of the committee calling upon the representatives of the manufacturer not only for information as to labor and other costs, both here and abroad, but also for detailed information concerning the research activities of the industry.

TO AUTHORS OF PAPERS

Authors of papers intended for presentation at the St. Louis meeting of the Society are requested to submit same for publication promptly, preferably in advance of the meeting. As far as possible, dates of publication will be determined by order of receipt by the Editor.

ORIGINAL PAPERS AND DISCUSSIONS

SOME RELATIONS OF COMPOSITION TO SOLUBILITY OF ENAMELS IN ACIDS[1]

By Homer F. Staley

ABSTRACT

Review of literature.—The literature on acid resisting enamels and glasses is reviewed.

Acid resisting powers produced by different oxides.—When substituted one for another, in each case in equal percentage amounts, various oxides and minerals increased the resistance of various enamels to the action of boiling 20 per cent hydrochloric acid in the following order of effectiveness: Al_2O_3, cryolite, Na_2O, PbO, BaO, Li_2O, MgO, CaF_2, ZnO, SrO, CaO, B_2O_3. The first five mentioned were especially effective. The remainder are undesirable materials from the standpoint of acid resistance.

Effect of the enamel base.—The relative effects of the materials were the same for various base enamel compositions.

Effect of ZrO_2 and TiO_2.—ZrO_2 and TiO_2, when substituted for small amounts of SiO_2, increased the resistance of various enamels to attack by acids, ZrO_2 being most effective in this respect. The favorable action of ZrO_2 is offset by a tendency to produce excessive chipping. Rutile gives less chipping than either zirconia or silica and greater acid resistance than silica.

Best compositions.—Enamels 2, 17, 19, 26, 27, and 33 of table 1 showed resistance to action of the acid equivalent to that of the original compoitions based on the analysis of a French acid-resisting enamel. By use of the data developed in this investigation other highly acid-resisting compositions can readily be formulated.

Although the manufacture of acid-resisting enameled wares in this country is a business of considerable magnitude and of constantly increasing technical importance, very little has been published in regard to the compositions used. The little that has appeared in print says nothing in regard to the relations of

[1] Received May 27, 1921. Published by permission of the Director, Bureau of Standards.

composition of the enamels used to solubility in acids. This question is of importance in the manufacture of wares to be used in making of chemicals, explosives, and certain food products. Manufacturers of enameled wares to be used in cooking and for other purposes in which the enamel will come into contact with dilute acids are also interested in this problem. This investigation was undertaken as an attempt to discover some of these relations.

Review of Literature

Work of Various Investigators.—Edward Orton, Jr.,[1] subjected three makes of enameled automobile tags of unknown composition to the action of boiling water for eight hours, boiling one per cent sulfuric acid for 15 minutes, and to exposure to the fumes of strong hydrochloric acid for 18 hours. The relative order of resistance of the three makes of enameled ware was the same in the three tests. Boiling in dilute sulfuric acid proved the most severe, and boiling in water the next in severity. No correlation was found between the chemical resisting properties and physical strength or beauty of appearance and finish of the enamels.

J. B. Shaw[2] made a study of the effect of variation of alumina silica and boric oxide in white enamels of the type used for coating cooking wares. The samples were boiled for 15 minutes in 1 per cent sulfuric acid and in 75 per cent acetic acid. The degree of attack was determined by the loss in weight per square inch. It was found in both these tests that the solubility increased as boric oxide increased. The action of 75 per cent acetic acid was similar to, but much less marked than, that of one per cent sulfuric acid.

In a second investigation of some white enamels for sheet steel Shaw[3] tested the enamels with lemon juice, a 10 per cent solution of citric acid and a 10 per cent solution of oxalic acid. The solutions were dropped on to the enamel surface and allowed to remain for periods of 10 minutes, 30 minutes, or until they evaporated to dryness. The degree of attack was judged by the ap-

[1] *Trans. Am. Ceram. Soc.*, **11,** 320–341 (1909).

[2] *Ibid.*, **12,** 463–494 (1910).

[3] Bur. Standards, *Tech. Paper*, No. **165,** 81–85.

pearance of the enamel. The author states that it was not possible to arrange the compositions in logical sequence, but draws the following conclusions, in which he considers the appearance of an "irridescent stain" followed by a loss of gloss or the appearance of a rough surface as "destruction:"

"1. Fluorine is decidedly detrimental to enamels which are subject to weak acid solutions. When added to enamels as fluorspar or cryolite in large or small amounts, it renders them subject to easy attack and destruction by ordinary lemon juice.

"2. Boric acid in easily fusible enamels renders them easily destroyed by weak acids, such as lemon juice, but in refractory enamels it can be used in small amounts and the enamels still maintain stability against acids. This conclusion is substantiated by the Pyrex and other chemical glasswares now on the market.

"3. No enamel of the borosilicate type made in this series was found proof against 10 per cent citric acid.

"4. Enamels containing no fluorine or boric acid can be easily made proof against citric acid, but it was not possible to reduce their refractoriness to a sufficiently low point to make them satisfactory as white enamels."

R. D. Landrum[1] tested 10 white enamels on sheet steel cooking utensils, including among the tests boiling to dryness 20 per cent acetic acid in small dishes. The amount of attack was gauged by the loss in weight. Owing to the wide variations in composition the author did not draw any conclusions from the acid tests. It is noteworthy that the compositions of several of the most resistant enamels were high in sodium oxide. There was no parallelism between chemical and physical excellence.

Action of Various Acids on Enamels.—The relative action on a given enamel of different acids and of various concentrations of the same acid has been studied by several investigators. R. D. Landrum[2] found that with acetic acid maximum attack occurred with a concentration of 20 per cent . The action of highly concentrated acids was almost negligible. E. P. Poste[3]

[1] *Trans. Am. Ceram. Soc.*, **14,** 489–509 (1912).

[2] *Ibid.*, **13,** 494–501 (1911).

[3] *Ibid.*, **17,** 137–149 (1915); **18,** 762–766 (1916); THIS JOURNAL, **2,** 32–43 (1919); **3,** 560–567 (1920).

determined the action on grains of enamel of acetic, citric, tartaric, hydrochloric, nitric and sulfuric acids. The results obtained were similar to those of Landrum. All the acids had their greatest solvent action at concentrations between 10 and 30 per cent. In the last citation he states also that a weak solution of citric acid impairs the gloss of some commerical enamels.

L. E. Frost[1] conducted tests with acetic acid upon finished enameled surfaces. He obtained results that checked those of Landrum and Poste.

The present writer[2] has shown that the degree of attack of the various acids and the various concentrations of the same acids used by Poste and Landrum was proportional to the hydrogen ion concentration in the various solutions. With all the acids used the ion concentration is low in dilute solutions, increases rapidly up to concentrations between 20 and 30 per cent of acids, then decreases gradually and becomes practically zero in highly concentrated acid solutions.

Action of Acids on Glass.—Since enamels are essentially glasses, the action on glass is of interest. The literature of this subject is reviewed at some length with reference to certain types of glass by Hovestadt.[3] In brief it has been found that in lime soda glasses with high silica (over 70 per cent SiO_2) the attack by acids is less than by pure water and diminishes with increased concentration of acid. The explanation given is that with water the effect on the glass is due primarily to the solution of alkali from the glass, and secondarily to the further action on the glass of the alkali thus set free, but acid if present neutralizes the alkali as fast as it is dissolved from the glass and thus presents the secondary attack. Compositions such as are described above are not suitable for enamels.

On the other hand the relative action of water and acid was found to be completely reversed from the above when it came to treatment of low silica glasses, such as high lead glasses and com-

[1] THIS JOURNAL, **1**, 422–428 (1918).

[2] Staley, Homer F., *Trans. Am. Ceram. Soc.*, **13**, 499 (1911); and **17**, 144–147 (1915).

[3] "Jena Glass," by H. Hovestadt; trans. by J. D. and Alice Everett, MacMillan and Co.

plex borosilicates. Water has little effect on such glasses, but they are attacked directly by acids, especially by hydrochloric. These compositions are of the type of glasses used for enamels and from the work of many investigators there seems to be no doubt that enamels are attacked directly by acids.

One important point treated briefly in the above mentioned review is that while calcium oxide gives glasses high resistance and sodium oxide low resistance to the attack of water, when it comes to attack by acids, calcium silicates are more readily attacked than sodium silicates.

Because of the contradictory results obtained by these various investigators and because of the lack of data on the solubilities in acid of the so-called acid resistance ware, a study of this type of enamel was deemed advisable. It was the desire of the author to develop enamels which could approach the French type in acid resistance and at the same time to gather information that would be helpful to enamelers as to the general effects of various oxides and minerals in the enamels on the solubilities of their products.

Experimental

The cover coat enamel of high grade, French, acid-resisting enamel served as the basis for the present investigation. The analysis in round numbers was as follows: SiO_2, 68; B_2O_3, 7; Na_2O, 19; CaO, 6; and is given as Enamel 1 in table 1. With this composition as a basis some seventy enamels were compounded by the method of calculated percentage composition melted.[1] In making the calculations all chemicals were considered pure and no fluorine was supposed to be lost.

TABLE 1

Composition of enamels with results of tests with boiling 20% hydrochloric acid. The letter "s" indicates that the enamels failed by softening. The letter "c" indicates that the enamels failed by chipping. The plus mark (+) indicates that the enamels could have endured the acid test longer if they had not failed by chipping, or after 1000 hours if the tests had not been discontinued.

No.	Composition in percentages					Hours endurance	Type of failure
	SiO_2	B_2O_3	Na_2O				
1	68	7	19	6	CaO	1000+	
2	68	7	19	6	ZnO	1000+	
3	68	7	11	14	ZnO	N.G.	chipped

[1] For method see Bur. Standards, *Tech. Paper*, No. **142**, p. 70.

TABLE I (*Continued*)

No.	Composition in percentages SiO_2	B_2O_3	Na_2O				Hours endurance	Type of failure
4	68	15	3	14	ZnO		N.G.	chipped
5	76*	11	2.5	10.5	ZnO		N.G.	chipped
6	ground coat							
7	ground coat							
8	68	15	11	6	ZnO		N.G.	blistered
9	68	11	11	10	ZnO		N.G.	blistered
10	68	13	7	12	ZnO		N.G	blistered
11	73*	11	6	10	ZnO		N.G.	blistered
12	60	15	19	6	ZnO		See No. 37	
13	60	7	19	14	ZnO		89	s
14	60	23	11	6	ZnO		See No. 36	
15	60	15	11	14	ZnO		See No. 42	
16	60	7	19	14	CaO		15	s
17	60	7	19	14	BaO		1000+	
18	68	7		6	ZnO	19 Li_2O	657	s
19	60	7	19	14	PbO		1000+	
20	60	7	19	14	Al_2O_3		N.G.	blistered
21	60	7	19	14	SrO		28	s
22	60	7	19	14	MgO		N.G.	blistered
23	60	21	19				14	s
24	60	14	19	7	Al_2O_3		26?	s
25	60	14	19	7	MgO		14	s
26	60	7	12	14	PbO	7 BaO	1000+	
27	60	7	12	7	PbO	14 BaO	1000+	
28	60	7	12	14	PbO	7 Al_2O_3	677+	c
29	60	7	14	14	PbO	7 CaO	344+	c
30	not made							
31	not made							
32	60	7	19	14	CaF_2		172	s
33	60	7	19	14	Cryolite		1000+	
34	67	14	12	7	ZnO		infusible	
35	60	14	12	7	ZnO	7 Al_2O_3	42	s
36	60	21	12	7	ZnO		3	s
37	60	14	19	7	ZnO		5	s
38	60	14	12	7	ZnO	7 CaO	3	s
39	60	14	12	7	ZnO	7 MgO	5	s
40	60	14	12	7	ZnO	7 BaO	5	s
41	60	14	12	7	ZnO	7 SrO	3	s
42	60	14	12	14	ZnO		3	s
43	60	14	12	7	ZnO	7 PbO	5	s
44	60	14	12	7	ZnO	7 Li_2O	3	s
46	60	14	12	7	PbO	7 TiO_2	5	s

* SiO_2 replaced by feldspar.

TABLE I (*Continued*)

No.	Composition in percentages SiO_2	B_2O_3	Na_2O				Hours endurance	Type of failure
47	not made							
48	60	14	12	7 PbO	7 Al_2O_3		146	s
49	60	14	19	7 PbO			313?	s
50	60	14	12	7 PbO	7 CaO		3	s
51	60	14	12	7 PbO	7 MgO		5	s
52	60	14	12	7 PbO	7 BaO		5	s
53	60	14	12	7 PbO	7 SrO		3	s
54	60	14	12	7 PbO	7 ZnO		3	s
55	60	14	12	14 PbO			34	s
56	60	14	12	7 PbO	7 CaF_2		3	s
57	60	14	12	7 PbO	7 cryolite		48	s
58	60	14	12	7 PbO	7 Li_2O		5	s
59	53	14	12	7 PbO	7 TiO_2	7 Al_2O_3	335	s
60	53	14	19	7 PbO	7 TiO_2		241	s
61	53	14	12	7 PbO	7 TiO_2	7 BaO	48	s
62	53	14	12	7 PbO	7 TiO_2	7 ZnO	3	s
63	53	14	12	14 PbO	7 TiO_2		48	s
64	53	14	12	7 PbO	7 TiO_2	7 CaF_2	3	s
65	53	14	12	7 PbO	7 TiO_2	7 cryo.	301	s
66	53	14	12	7 PbO	7 TiO_2	7 Li_2O	5	s
67	53	14	12	7 PbO	7 ZrO_2	7 Al_2O_3	106+	c
68	53	14	19	7 PbO	7 ZrO_2		106+	c
69	53	14	12	7 PbO	7 ZrO_2	7 BaO	82+	c
70	53	14	12	7 PbO	7 ZrO_2	7 ZnO	58+	c
71	53	14	12	14 PbO	7 ZrO_2		136+	c
72	53	14	12	7 PbO	7 ZrO_2	7 CaF_2	44	s
73	53	14	12	7 PbO	7 ZrO_2	7 cryo.	386	s
74	53	14	12	7 PbO	7 ZrO_2	7 Li_2O	44	s

The enamels were melted in two kilogram batches in crucibles until bubbling ceased and were then quenched by being poured into cold water. The resultant glasses were dried and ground to powder in ball mills. The test specimens were oval bottomed cast iron cups. These were coated with a rather refractory ground coat, which contained two frits, W-6 and W-7:

W-6 Frit	
Flint	350
Borax	185
Sodium nitrate	35
Red lead	41

W-7 Frit	
Flint	519
Borax	345
Litharge	37

The mill batch was as follows:

W-6 Frit	250
W-7 Frit	369
Flint	172
Clay	112
Cobalt oxide	1.2
Water	600

Grind to pass an 80-mesh sieve

The temperature of firing of the ground depended on the particular cover enamel being applied, and ranged from 800°C to 950°C with corresponding decreases in the time from 18 minutes to three minutes. The cover enamel took considerably less time in each case, this varying from 10 minutes to about 45 seconds. The size and thickness of the iron casting and type of furnace have such great effects on the time and temperature of firing that it is impossible to give data which will have a direct relation to actual commercial conditions. It is well to note, however, that some of the refractory compositions gave best results at lower temperatures with a long firing period, as the enamels were so viscous that it was necessary to drive off all gas and entrapped air previous to fusing of the enamel.

The powdered cover enamel was applied by sifting in the manner commonly used for making cast iron enameled wares by the dry-powder process. In most cases it was necessary to make two applications of cover enamel in order to get a coating of sufficient uniformity of thickness. The enameled cups cooled normally upon removal from the furnace. There was no apparent development of crazing in any of the enamels.

Twenty per cent hydrochloric acid was chosen for testing the acid resistance of the enamels. A mineral rather than an organic acid was selected because the former appears to be more destructive on the types of compositions used, which was also the case with those tested by other investigators mentioned in the introduction of the paper. Hydrochloric was selected in preference to sulfuric acid because the latter forms insoluble compounds with several of the constituents used in this series of enamels. Hydrochloric acid is preferable to nitric for testing purposes, for while a nitric acid solution constantly changes in composition when boiled, a twenty per cent hydrochloric acid solution remains constant in composition.

The acid resistance tests were made by placing the cups on a steam bath and keeping them filled with the acid solution for a period of 1000 hours unless the enamel failed before that time. In order to avoid an accumulation of salts in the cups, they were washed out and filled with entirely new acid solution every seven hours.

It is questionable whether the loss of weight of an enamel surface is a true criterion of the degree of attack by the acid. In some cases an enamel will take up radicals from the acid solution and actually increase in weight while it is undergoing disintegration. Moreover, in the present investigation this method was out of the question because of the progressive chipping of the enamel coating that took place with many compositions and because of the progressive oxidation and scaling of the exterior of the cups. The first impairment of the lustre of the enamel surface is not a true indication of lack of resistance to acids, for many enamels will undergo this impairment of lustre and then resist the action of acid solutions indefinitely.

E. P. Poste[1] has well described the difference of surface appearance of an enamel produced by different degree of acid action, as follows:

"If the action is very slight a peculiar surface discoloration develops to a loss of gloss and a lighter color. The surface can be definitely scratched with a knife. As the action again increases, the more soluble constituents of the enamel go into solution, and leave behind a very fine, white powder which can be rubbed off when the surface is dry. This condition is termed 'chalking' and indicates a very severe action."

Since we wished to determine the point at which the enamel coating would be no longer suitable for use in chemical apparatus, where there is the possibility of a certain amount of mechanical as well as chemical action, we took as the point of failure the time at which the surface of the enamel had softened sufficiently to permit of being definitely scratched with a pointed knife blade. A few simple tests showed that the variations of results due to different operators and different knife

[1] *Trans. Am. Ceram. Soc.*, **19**, 150 (1917).

blades were not sufficiently great to disturb the relative order of resistance of the various enamels tested. While the method is admittedly crude, it conforms to the method by which acid-resisting wares are condemned in use. Fortunately for our work the various oxides and minerals used had either a definitely beneficial or detrimental effect on acid resistance in the range of variations we employed, and, therefore, by making cross-comparisons we were able to determine rather accurately for the type of compositions used, the relative effect of the various oxides and minerals on acid resistance.

The calculated composition of the various enamels and the results of the tests are shown in table 1. In this table the letter "s" indicates that the enamel failed by softening; the letter "c" indicates that the enamel failed by chipping, the plus sign after certain figures for hours of endurance indicates that as far as resistance to acids was concerned the sample could have endured the acid treatment for a longer time.

Discussion of Results

It is possible to rearrange the data shown in table 1 in various tables in any one of which the compositions will differ from each other only by one variable portion. Examples of the many possible arrangements illustrating the effect of oxides and radicals other than SiO_2, TiO_2 and ZrO_2 are shown in tables 2 to 8. A summary of these tables is given in table 9.

TABLE 2

Constant portion: 60 SiO_2, 7 B_2O_3, 19 Na_2O.
Variable portion: 14 parts.

No.	Variable	Hours endurance	Type of failure
35	Cryolite	1000+	
19	PbO	1000+	
17	BaO	1000+	
32	CaF_2	172	Softening
13	ZnO	89	Softening
21	SrO	28	Softening
16	CaO	15	Softening
23	B_2O_3	14	Softening

TABLE 3

Constant portion: 60 SiO_2, 14 B_2O_3, 12 Na_2O, 7 ZnO
Variable portion: 7 parts

No.	Variable	Hours endurance	Type of failure
35	Al_2O_3	42	Softening
37	Na_2O	5	Softening
43	PbO	5	Softening
40	BaO	5	Softening
39	MgO	5	Softening
42	ZnO	3	Softening
41	SrO	3	Softening
38	CaO	3	Softening
36	B_2O_3	3	Softening

TABLE 4

Constant portion: 60 SiO_2, 7 B_2O_3, 12 Na_2O, 14 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
28	Al_2O_3	677+	Chipping
19	Na_2O	1000+	
26	BaO	1000+	
29	CaO	345+	Chipping
55	B_2O_3	34	Softening

TABLE 5

Constant portion: 60 SiO_2, 7 B_2O_3, 12 Na_2O, 7 BaO, 7 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
26	PbO	1000+	
27	BaO	1000+	
52	B_2O_3	5	Softening

TABLE 6

Constant portion: 53 SiO_2, 7 TiO_2, 14 B_2O_3, 12 Na_2O, 7 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
59	Al_2O_3	335	Softening
65	Cryolite	301	Softening
60	Na_2O	241	Softening
63	PbO	48	Softening
61	BaO	41	Softening
66	Li_2O	5	Softening
64	CaF_2	3	Softening
62	ZnO	3	Softening

TABLE 7

Constant portion: 53 SiO_2, 7 ZrO_2, 14 B_2O_3, 12 Na_2O, 7 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
67	Al_2O_3	106+	Chipping
73	Cryolite	386	Softening
68	Na_2O	106+	Chipping
71	PbO	136+	Chipping
69	BaO	82+	Chipping
74	Li_2O	44	Softening
72	CaF_2	42	Softening

TABLE 8

Constant portion: 60 SiO_2, 14 B_2O_3, 12 Na_2O, 7 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
48	Al_2O_3	146	Softening
57	Cryolite	48	Softening
49	Na_2O	313?	Softening
55	PbO	34	Softening
52	BaO	5	Softening
58	Li_2O	5	Softening
51	MgO	5	Softening
56	CaF_2	3	Softening
54	ZnO	3	Softening
53	SrO	3	Softening
50	CaO	3	Softening

TABLE 9

Summary of results in Tables 2–8.

Results are stated in hours endurance. The plus sign (+) following 1000 (thus 1000+) indicates that the sample did not fail in 1000 hour's test. In other cases the sign indicates that the sample failed by chipping before it softened sufficiently to be scratched.

Variable	2	3	4	5	6	7	8
Al_2O_3		42	677+		335	106+	146
Cryolite	1000+				301	386	48
Na_2O		5	1000+		241	106+	
PbO	1000+	5		1000+	48	136+	34
BaO	1000+	5	1000+	1000+	41	82+	5
Li_2O					5	44	5
MgO		5					5
CaF_2	172				3	42	3
ZnO	89	3			3		3
SrO	28	3					3
CaO	15	3	345+				3
B_2O_3	14	3	34	5			

TABLE 10

Comparison of effects of ZrO_2 (table 7), TiO_2 (table 6), and SiO_2 (table 8).
Constant portion: 53 SiO_2, 14 B_2O_3, 12 Na_2O, 7 PbO.
Variable portion: 7 parts series, 7 parts group.
Results are stated in hours endurance. The + sign indicates that the sample failed by chipping.

Series variable	Group variable						
	Al_2O_3	Cryolite	Na_2O	PbO	BaO	Li_2O	CaF_2
ZrO_2	106+	386	106+	136+	82+	44	42
TiO_2	335	301	241	48	41	.5	3
SiO_2	146	48	34	5	5	5	3

It was not possible to show the effect of all the oxides in any one series on account of the wide variation of the effect of these on chipping and acid resistance. In series with a refractory glass base, many of the oxides caused excessive chipping (see table 7). In series with a fusible glass base the resistance to acids was so low in many cases that comparison was difficult (see table 3). The use of various base glasses and cross references is an advantage in that it enables us to determine whether the relative effect of the various materials is the same in different enamels.

These tables show that when substituted for one another in equal percentage amounts, the various materials affected the resistance of the enamels to acids in the following order, the most advantageous being named first: Al_2O_3, cryolite (Na_3AlF_6), Na_2O, PbO, BaO, Li_2O, MgO, CaF_2, ZnO, SrO, CaO, B_2O_3. This order of effect is found in all tables with the exception of the position of sodium oxide in table 8. The endurance of this particular enamel (number 49) was entirely out of proportion to that of other very similar compositions, and there is little doubt that there is some error in the record. The only other case of a doubtful record among all the enamels tested is that of number 24. In this case the endurance is too low.

The oxides and minerals fall into two rather distinct groups, one of which contains materials having a decidedly favorable effect on acid resistance when substituted for others in the list, the other containing materials having an unfavorable effect. In the group of desirable materials are: Al_2O_3, cryolite, Na_2O, PbO, BaO. In the group of undesirable substitutes are: Li_2O, MgO, CaF_2, ZnO, SrO, CaO, B_2O_3.

The presence of cryolite in the groups of favorable substitutes is rather remarkable, for according to J. B. Shaw[1] addition of cryolite has detrimental effect on the acid resistance of enamels. However, it must be remembered that we are speaking here of the effect of substitution of cryolite for other materials in equal percentage amounts. Shaw was writing of the addition of fluorine to an enamel formula, which would decrease the percentage of all the other ingredients, including silica, in the enamel. The position of cryolite in our results is established by its place in four series of enamels. That the fluorine was not volatilized from the composition during smelting was shown by the fusibility of the enamels and also by the fact that 6.3 per cent fluorine was found in the melted enamel. It may be added that the cryolite-bearing enamels could be given slight scratches at the beginning of the acid tests but afterward became more resistant.

The presence of Na_2O in the group of favorable oxide substitutes and of ZnO and CaO among the unfavorable ones is also contrary to current assumptions in regard to resistance of glass to chemical action. As pointed out in the discussion of the action of acids on glass, the types of compositions used for making glasswares are high in silica and are attacked by water more than by acids. In the case of soft glasses, such as were used for enamels in this investigation, there is a direct attack of the glass by acids and relations of composition to resistance may be entirely different in the two cases. Zinc oxide is a common constituent of chemical glasswares[2] but these are so high in silica that the qualitative differences in effect of the basic oxides are negligible. Sodium oxide has another decided advantage over zinc and calcium oxides in that it produces more fusible glasses and, therefore, permits the use of a higher percentage of silica than either zinc oxide or calcium oxide. In fact, it is rather difficult to make a highly acid resistant enamel without the use of considerable sodium oxide. The presence of a high percentage of Na_2O in the French enamel, used as the basis of the series of enamels, and its place near the top of four series of enamels made by us, fixes its standing rather definitely.

[1] Bur. Standards, *Tech. Paper*, No. **165**, p. 84.

[2] Bur. Standards, *Tech. Paper*, No. **107**, p. 8.

The effects of substituting ZrO_2 and TiO_2[1] for SiO_2 are shown in table 10. It will be seen that ZrO_2 gives highest resistance followed in order by TiO_2 and SiO_2. However, the substitution of seven per cent of ZrO_2 for silica caused excessive chipping. On the other hand substitution of TiO_2 made more fusible enamels and reduced chipping. The favorable action of TiO_2 is probably the reason for its use in limited quantities by most manufacturers of acid-resisting enameled wares.

Conclusions

1. When substituted one for another, in each case in equal percentage amounts, various oxides and minerals increased the resistance of various enamels to the action of boiling 20 per cent hydrochloric acid in the following order of effectiveness: Al_2O_3, cryolite, Na_2O, PbO, BaO, Li_2O, MgO, CaF_2, ZnO, SrO, CaO, B_2O_3.

The first five mentioned were especially effective. The remainder are undesirable materials from the standpoint of acid resistance.

2. The relative effects of the materials were the same for various base enamel compositions.

3. ZrO_2 and TiO_2, when substituted for small amounts of SiO_2, increased the resistance of various enamels to attack by acid, ZrO_2 being most effective in this respect.

The favorable action of ZrO_2 is offset by a tendency to produce excessive chipping. Rutile gives less chipping than either zirconia or silica and greater acid resistance than silica.

4. Enamels 2, 17, 19, 26, 27, and 33 of table 1 showed resistance to action of the acid equivalent to that of the original composition based on the analysis of a French acid-resisting enamel.

By use of the data developed in this investigation other highly acid-resisting compositions can readily be formulated.

BUREAU OF STANDARDS
WASHINGTON, D. C.

[1] Rutile from American Rutile Co., 95% TiO_2, 1½% Fe_2O_3, 3.5% SiO_2

HIGH FIRE PORCELAIN GLAZES[1]

By H. H. Sortwell

ABSTRACT

Field covered.—The glazes studied covered the field 3.0 to 13.0 equivalents SiO_2 and 0.3 to 3.25 equivalents Al_2O_3 between the Al_2O_3: SiO_2 ratios of 1:4 and 1:20. The RO was maintained at 0.7 CaO and 0.3 K_2O.

Deformation temperatures.—The deformation temperatures were determined by cones in a small gas furnace heated at the rate of 50°C per hour. The deformation temperatures are shown graphically by isotherms. The results of the part of the field previously covered by Stull and Howat agree with their work. It was found that there is a deformation eutectic axis at a slight inclination to the ordinate representing Al_2O_3 up to 7.0 equivalents SiO_2. Above 7.0 equivalents the inclination rises, and at 11.0 equivalents SiO_2 it increases much more.

Firing tests.—The glazes were applied to porcelain cups biscuited at cone 08, and fired to cones 10, 12, 14 and 16. The cone 10 test was made only for comparison, since Stull and Howat had previously covered a small part of the field at cones 9 and 11.

The glazes are plotted both by empirical formulas and batch weights, showing the location of the best glazes at the different temperatures.

In agreement with Stull's statement, increase in Al_2O_3 in this type of glaze decreases crazing. Increase in SiO_2 will not decrease crazing but if carried far enough will cause crazing to occur.

From cone 12 to cone 16 the best glazes have Al_2O_3 and SiO_2 contents corresponding to the approximate formula $Al_2O_3 = 0.3 + {}^1/_{12}\ SiO_2$.

Introduction.—A great deal of material has been published on porcelains of all types, but systematic information on porcelain glazes fired at higher temperatures is more limited.

Stull[2] thoroughly covered the field for glazes maturing at cone 11. Stull and Howat[3] investigated the field at cone 9 and reported deformation temperature studies for the glazes made.

[1] Received June 29, 1921. Published by permission of the Director, Bureau of Standards.

[2] *Trans. Am. Ceram. Soc.*, **14**, 62–67 (1912).

[3] *Ibid.*, **16**, 454–460 (1914).

Since no detailed information was to be had on glazes of this type for high fire porcelain, chemical porcelain, spark plugs, pyrometer tubes, etc., maturing from cone 12 to cone 16, the following investigation was undertaken.

Compositions Studied.—As originally laid out the field consisted of 35 members with 3, 4, 5, 7, 9, 11, and 13 equivalents of silica, and alumina corresponding to alumina-silica ratios of 1:10, 1:8, 1:6, 1:5, and 1:4. The RO members were constant at 0.7 and 0.3 K_2O. This covered the field with fair uniformity when plotted both by the empirical formula method and by batch weights. Later, to round out the deformation tempera ture study, 15 additional glazes were made with silica 4, 5, 7, 9, 11, and 13 equivalents with the alumina-silica ratio of 1:12; silica 5, 7, 9, 11 and 13 equivalents with the alumina-silica ratio of 1:15; and silica 7, 9, 11, and 13, equivalents with the alumina-silica ratio of 1:20.

Procedure.—The glazes were weighed out separately in one kilogram batches and ground three hours in small ball mills. The materials used analyzed as follows:

	Flint	N.Carolina kaolin	Maine feldspar	Whiting
SiO_2	98.43	41.96	72.85	0.91
Fe_2O_3	.26	.52	.48	.30
Al_2O_3	.80	35.95	15.45	.34
CaO	——	.24	.31	55.02
K_2O	——	——	7.89	——
Na_2O	——	——	2.31	——
MgO	——	——	——	.44
Loss on ignition	.14	20.40	.25	43.44
	99.63	99.07	99.54	100.45

A small quantity of each glaze was evaporated to dryness and moulded into test cones for the deformation temperature determinations, which were made in a small gas furnace. The temperature was raised to 1100°C in one hour and from 1100°C on at the rate of 50° per hour. The temperature measurements were made with a platinum platinum-rhodium thermocouple and a Leeds-Northrup potentiometer indicator. Five cones were tested at a time, the thermocouple junction being within

three-eighths of an inch from each cone. Uniform temperatures were maintained within the furnace as shown by Orton cones Two or more determinations were made on each glaze, checks within 5°C being obtained.

The glazes were applied, by dipping, on porcelain cups 2½ inches in diameter, 2½ inches deep and 1/8 inch thick which had previously been biscuited to cone 08 in a slow oxidizing fire. The composition of the mixture used was as follows:

North Carolina kaolin	31
Florida kaolin	12
Tenn. ball clay No. 5	5
Flint	34
Feldspar	18

Four firing tests were made in a gas-fired kiln, to cone 10 in 20 hours, to cone 12 in 20 hours, to cone 14 in 22 hours and to cone 16 in 24 hours. Reducing conditions were maintained up to cone 8 but from that point on reduction was diminished until the fire was neutral or slightly oxidizing at the finish.

Deformation Temperatures.—The silica and alumina equivalents of all the glazes and their deformation temperatures are given in table 1. The deformation eutectic axis in the part of the field previously covered practically agrees with the work of Stull and Howat although the softening temperatures found in the present work are lower, as would be expected due to the slower rate of heating. Since the field was not covered as closely in this work, the slighter variations are not shown.

TABLE I

No.	Al_2O_3	SiO_2	Al_2O_3 : SiO_2	Deformation temperature, °C	No.	Al_2O_3	SiO_2	Al_2O_3 : SiO_2	Deformation temperature, °C
1	0.300	3.0	1:10	1173	26	1.100	11.0	1:10	1275
2	.375	3.0	1:8	1146	27	1.375	11.0	1:8	1278
3	.500	3.0	1:6	1109	28	1.833	11.0	1:6	1300
4	.600	3.0	1:5	1109	29	2.200	11.0	1:5	1350
5	.750	3.0	1:4	1134	30	2.750	11.0	1:4	1418
6	.400	4.0	1:10	1137	31	1.300	13.0	1:10	1315
7	.500	4.0	1:8	1115	32	1.625	13.0	1:8	1317
8	.666	4.0	1:6	1114	33	2.166	13.0	1:6	1336
9	.800	4.0	1:5	1124	34	2.600	13.0	1:5	1386
10	1.000	4.0	1:4	1210	35	3.250	13.0	1:4	1461

TABLE I (*Continued*)

No.	Al_2O_3	SiO_2	Al_2O_3: SiO_2	Deformation temperature, °C	No.	Al_2O_3	SiO_2	Al_2O_3: SiO_2	Deformation temperature, °C
11	0.500	5.0	1:10	1124	A_1	0.333	4.0	1:12	1175
12	.625	5.0	1:8	1157	A_2	.416	5.0	1:12	1151
13	.833	5.0	1:6	1157	A_3	.583	7.0	1:12	1148
14	1.000	5.0	1:5	1173	A_4	.750	9.0	1:12	1183
15	1.250	5.0	1:4	1223	A_5	.916	11.0	1:12	1252
16	.700	7.0	1:10	1147	A_6	1.083	13.0	1:12	1317
17	.875	7.0	1:8	1159	B_1	.333	5.0	1:15	1169
18	1.166	7.0	1:6	1208	B_2	.466	7.0	1:15	1149
19	1.400	7.0	1:5	1218	B_3	.600	9.0	1:15	1180
20	1.750	7.0	1:4	1292	B_4	.733	11.0	1:15	1230
21	.900	9.0	1:10	1209	B_5	.867	13.0	1:15	1376
22	1.125	9.0	1:8	1224	C_1	.350	7.0	1:20	1207
23	1.500	9.0	1:6	1230	C_2	.450	9.0	1:20	1237
24	1.800	9.0	1:5	1248	C_3	.550	11.0	1:20	1398
25	2.250	9.0	1:4	1370	C_4	.650	13.0	1:20	1410

The results are plotted for the molecular variations of alumina and silica (figure 1) and for the batch weights (figure 2), for which the glazes were calculated into percentages of clay, flint and fluxes (feldspar and whiting in the proportion of 167 feldspar to 70 whiting).

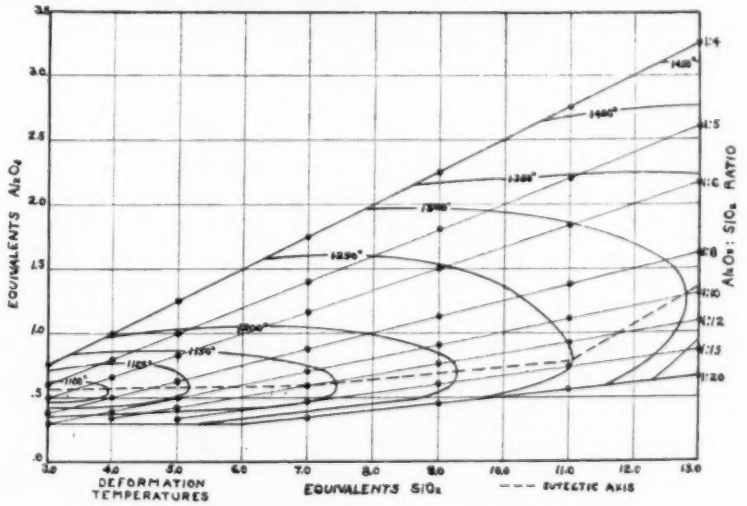

FIG. 1.

As shown in figure 1, increase in silica to 11 equivalents maintaining the alumina constant has little effect in comparison with alumina in increasing the deformation temperature as the isotherms run in the general direction of the alumina ordinate up to 11 equivalents. Beyond this figure increase in silica has a more pronounced effect on the deformation temperature.

Starting with 0.3 Al_2O_3 and any silica content, increasing the Al_2O_3 lowers the deformation temperature until the eutectic axis is crossed. Further increase in Al_2O_3 raises the deformation temperature.

The deformation eutectic axis lies at a slight inclination to the ordinate. As the silica content approaches seven equivalents, this inclination rises and at 11 equivalents it increases much more.

Examination of figure 2 shows that increasing flint does not greatly increase the deformation temperature until the composition approaches 60% flint. Further increase in flint increases the temperature rapidly.

Starting with zero clay, additions of clay first lower the deformation temperature, after which further increments of clay increase the temperature gradually until 45% clay is approached. From that point the temperature increase with increments of clay is more abrupt.

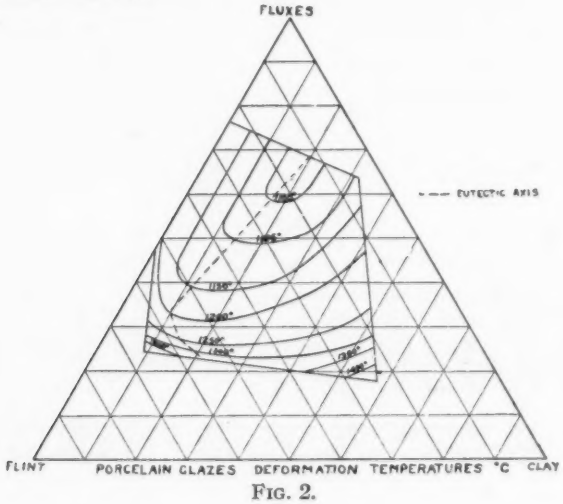

FIG. 2.

Decrease in the flux content (feldspar and whiting) increases the temperature of deformation gradually until it approaches 30%, after which further reductions cause a rapid rise in temperature.

The deformation eutectic axis starts at approximately 20% clay, 10% flint and 70% fluxes and runs in a straight line to approximately 10% clay, 55% flint and 35% fluxes. At this point the axis deflects to a higher clay content.

A plaster of Paris solid diagram was made of the field as plotted in figure 2 and is shown in figure 3. This shows plainly within what wide limits the more fusible glazes fall.

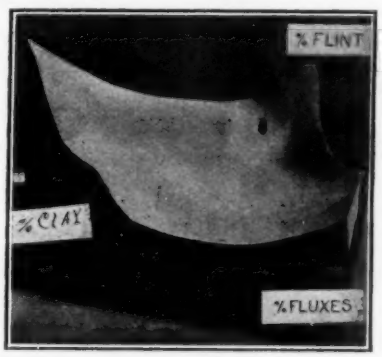

FIG. 3.

Cone 10 Firing Test.—In figures 4 and 5 are shown the results of the cone 10 firing test. At this heat treatment only a small part of the field is bright and the crazed area is comparatively large.

It will be noted that there is a belt surrounding the bright area in which the glazes are of semi-mat appearance, and surrounding this are glazes of mat appearance. The latter have the characteristic mat texture due to high alumina while for the high silica glazes the term mat appearance is used only as a criterion of maturity. Outside of the mat area the glazes are dry and immature.

Figure 4 shows that the obvious way to correct crazing in this type of glaze is to increase the alumina content by addition of clay.

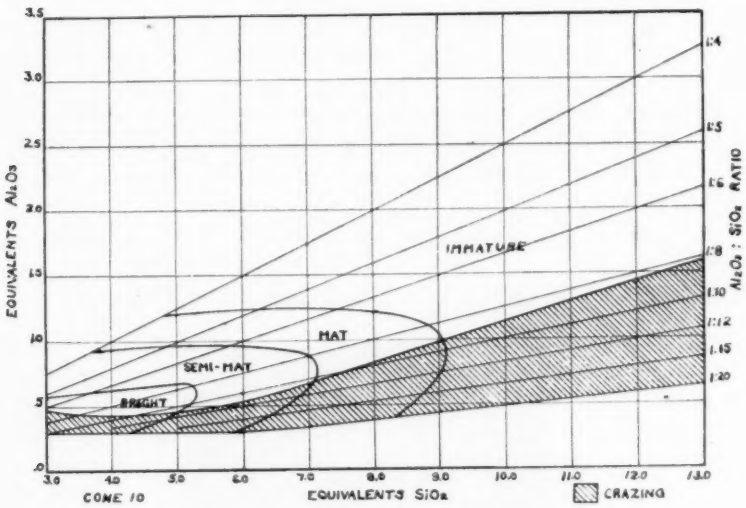
EQUIVALENTS Al_2O_3
3.5
3.0
2.5
2.0
1.5
1.0
.5
.0
IMMATURE
MAT
SEMI-MAT
BRIGHT
1:4
1:5
1:6
1:8
1:10
1:12
1:15
1:20
Al_2O_3 : SiO_2 RATIO
3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0
CONE 10
EQUIVALENTS SiO_2
CRAZING

FIG. 4.

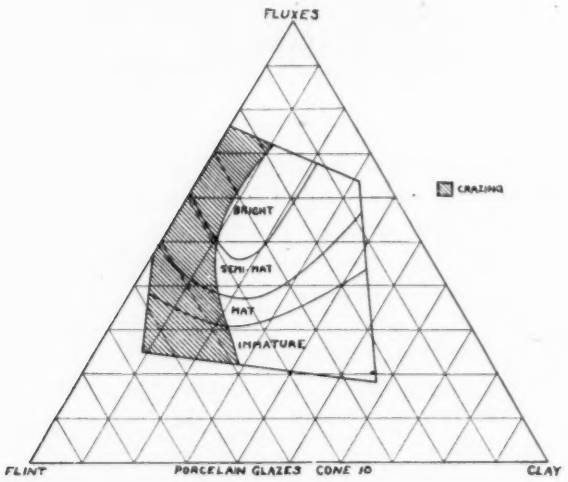
FLUXES
CRAZING
BRIGHT
SEMI-MAT
MAT
IMMATURE
FLINT
PORCELAIN GLAZES CONE 10
CLAY

FIG. 5.

Cone 12 Firing Test.—At cone 12, figures 6 and 7, the area of good bright glazes has increased and the crazing area receded as would be expected. Glazes 2, 3 and 4, show signs of overfiring as evidenced by the formation of bubbles which were not pres-

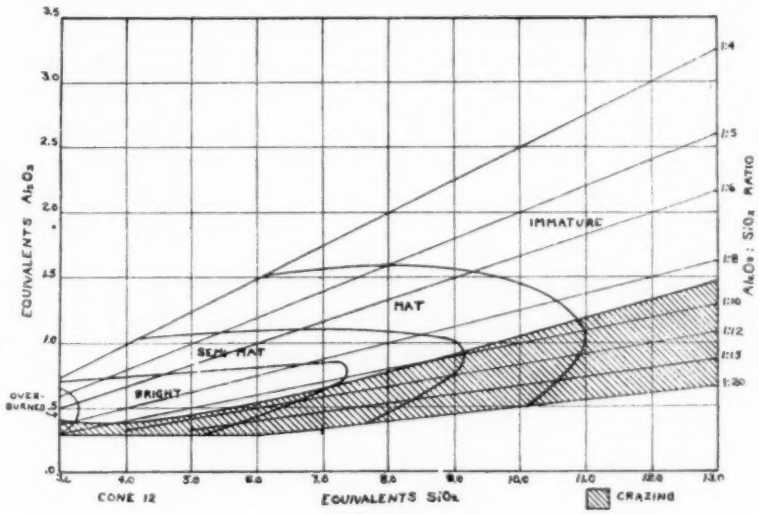

FIG. 6.

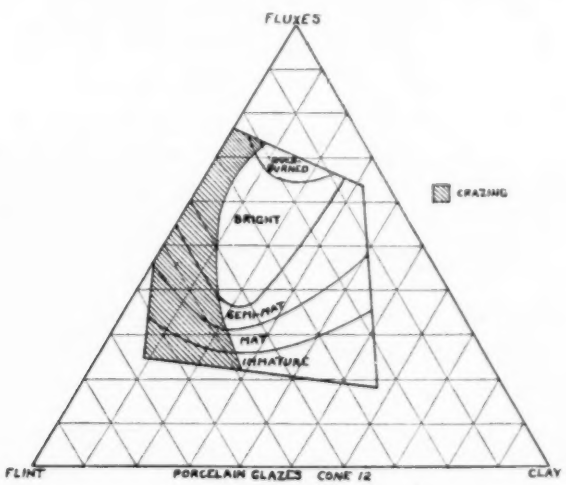

FIG. 7.

ent at cone 10. The semi-mat and mat areas have shifted position in accordance with the change in the area of bright glazes.

Glazes C_1, C_2, C_3, C_4, B_3, B_4, and B_5, which are the high silica glazes of lowest alumina content and the only glazes of 55 or more per cent flint, show signs of segregation at this temperature. This evidenced itself by lines on the surface of the glaze similar to watermarks but rising from the surface instead of being depressions. It appeared as if the fluxes were drawn to the inside of the glaze leaving a skeleton of flint at the surface. With the contraction of the test piece during firing, these high flint glazes did not follow, and consequently had to rise from the surface of the trial piece.

Cone 14 Firing Test.—Figures 8 and 9 show that at cone 14 the area of bright glazes and the area of overfired glazes has increased, the crazed area receded still further, with the semi-

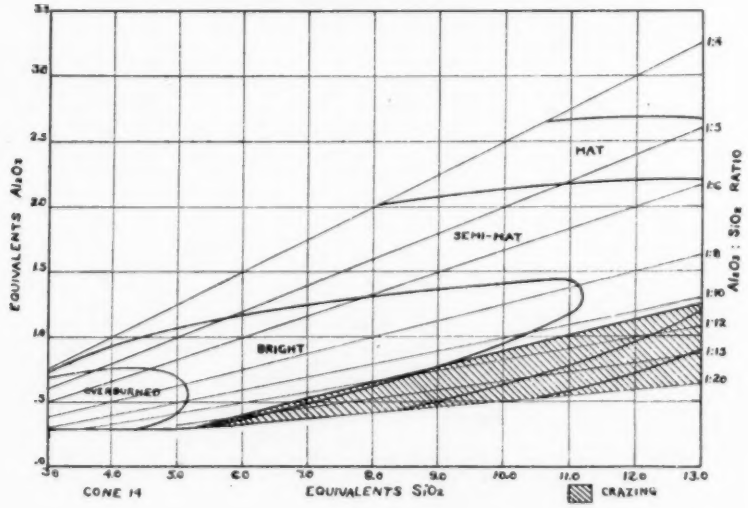

FIG. 8.

mat and mat areas shifted again. The softer of the over-fired glazes at this temperature were full of bubbles and had run to the bottom of the piece badly.

It was interesting to note that glazes 2 and 3, which were badly overfired and were far out of the craze area at this heat treatment, were crazed. No. 3 had been sound at cone 10 and cone 12. This seems to be evidence that when this type of glaze is overfired sufficiently, its composition or its physical state is changed enough to cause crazing. The 7 glazes containing 55 or more per cent of flint showed segregation as at cone 12.

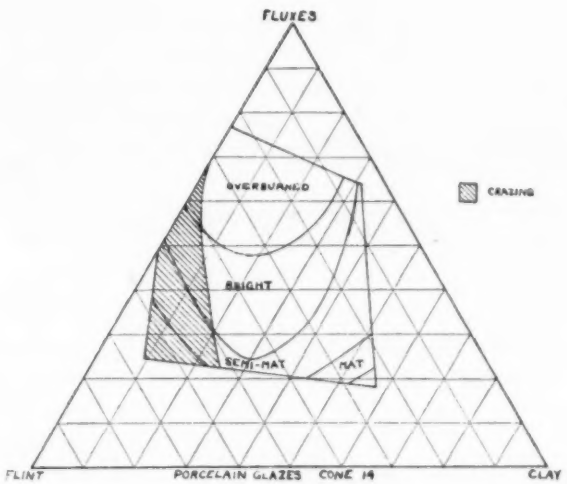

FIG. 9.

Cone 16 Firing Test.—At cone 16, figures 10 and 11, the area of bright glazes crosses the entire field, the area of overfired glazes is enlarged and the crazed area smaller. The semi-mat and mat areas have shifted in accordance with the change in the bright area.

The glazes which were overfired at cone 14 were not included in the cone 16 test so that further observation of the effect of overfiring on crazing was not available, as none of the glazes which were overfired at cone 16 but matured at cone 14 had been overfired as much as glazes 2 and 3 at cone 14. The segregation is present in the same glazes at cone 16 as at cone 14.

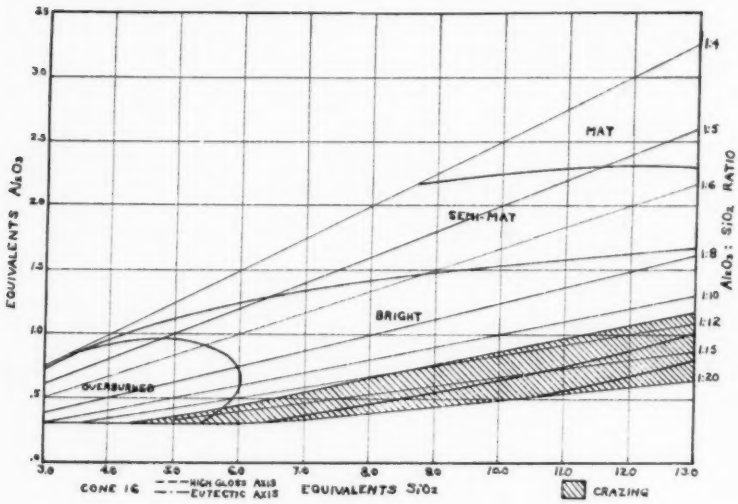
EQUIVALENTS Al_2O_3
Al_2O_3 : SiO_2 RATIO
MAT
SEMI-MAT
BRIGHT
OVERBURNED
1:4
1:5
1:6
1:8
1:10
1:12
1:15
1:20
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
CONE 16
HIGH GLOSS AXIS
EUTECTIC AXIS
EQUIVALENTS SiO_2
CRAZING

FIG. 10.

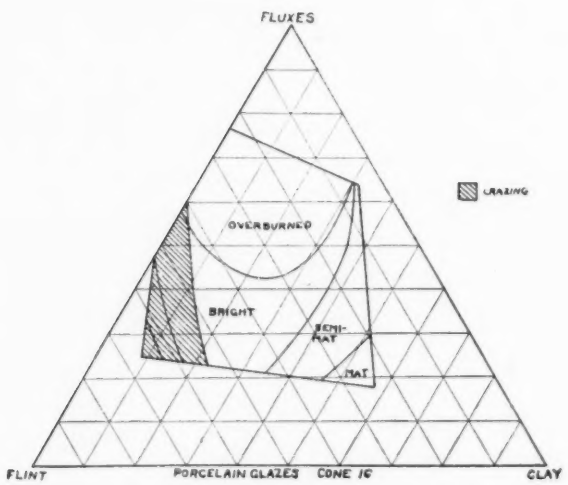
FLUXES
CRAZING
OVERBURNED
BRIGHT
SEMI-MAT
MAT
FLINT
PORCELAIN GLAZES CONE 16
CLAY

FIG. 11.

It is to be noted that although a great many of these mat glazes are such due to immaturity, as may be seen by following the charts through the successive tests, those mats and semi-mats in which the alumina silica ratio is as high as 1:4 for 3–6 equivalents of silica and as low as 1:6 at 10 equivalents of silica (see figure 10) are not mats of immaturity. Glazes 5, 10 and 15 which have lower deformation points than most of the bright glazes at cone 16 are still semi-mats. Glaze No. 5 with a deformation temperature of 1134° is still a semi-mat at cone 16.

In figure 11 the high gloss axis and the deformation eutectic axis are plotted for comparison. Except in the vicinity of 0.3 equivalents silica the best glazes of a given silica content are higher in alumina and a trifle harder than the most fusible glaze of that silica content. The eutectic axis lies partially in the crazed area.

Conclusions

There is a wide range of commercially acceptable bright glazes of this type maturing from cone 12 to cone 16 having a heat range of from four to five cones.

The best glazes lie along a high gloss axis which is practically a straight line represented by the approximate formula $Al_2O_3 = 0.3 + {}^1/_{12}\ SiO_2$.

The range in silica content for a given temperature is wide and becomes greater as the maturing temperature is raised, the possible variations being between 3 to 13 equivalents of SiO_2. The range in alumina content for a given temperature is very much narrower than the range in silica content.

There is a deformation eutectic axis for this series which lies below the high gloss axis and partially in the crazing area.

The best bright glazes for each heat treatment are found at the center of the area of mature good glazes on the chart.

Mat glazes of this type in which the alumina is high enough to give an alumina: silica ratio of 1:4 for 3 to 6 equivalents of silica and tapering down to 1:6 for 10 equivalents silica are aluminous mats and not mats of immaturity since increasing heat treatment will not change them to bright glazes.

Glazes of this type containing 55% or more flint show segregation and will not lie down to smooth surfaces from cone 12 to cone 16.

The proper way to correct crazing in this type of glaze is by increasing the alumina through the addition of clay. Higher firing causes the crazing area to recede but not enough to make higher firing a safe way to correct crazing, except in the glazes containing 4 or less equivalents of silica. There seems to be evidence that this type of glaze will craze when overfired sufficiently, which might be worthy of further investigation.

Addition of flint to this type of glaze will not stop crazing, but if carried far enough may throw the composition of the glaze into the crazed area. This is in agreement with Stull who found that Seger's rule did not hold for this type of glaze.

The writer wishes to acknowledge and to express his appreciation of the advice and suggestions of Mr. A. V. Bleininger in this work, and to thank Mr. Robert Sherwood for making the bisque.

BUREAU OF STANDARDS
WASHINGTON, D. C.

A TERRA COTTA INDUSTRY FOR OHIO[1]

By Arthur S. Watts

ABSTRACT

Two terra cotta industries using Ohio clays existed in Ohio prior to 1860. Today no terra cotta industries exist within the State, although Ohio has the clay, fuel and skilled labor. One Ohio clay, the Tionesta or No. 3 B, is especially adapted for terra cotta. It crosses the state through Vinton, Hocking, Perry, Muskingum, Coshocton, Tuscrawas and Stark Counties.

The occurrences and chemical composition as determined by the Ohio Geol. Survey are given by the author.

This clay burns with a shrinkage of about 6 per cent and a porosity of about 8 per cent from cone 2 to cone 5 with practically no color variation. It will carry its own weight of non-plastic without serious loss of mechanical strength.

Successful combinations and working directions for body, engobe, glaze and vitreous slip are given.

Ohio is recognized as the leading state in the Union as regards production of clay products and the question "Why is there no terra cotta industry in Ohio?" has frequently been asked. This question is hard to answer. Through the courtesy of the Ohio Geological Survey I have the information that Ohio was one of the pioneers in terra cotta manufacture. The Federal Census of 1860 shows that at Cincinnati there were two terra cotta plants in 1859. Mr. N. U. Walker added in 1878 to his general plant at East Liverpool a department for the manufacture of terra cotta. This was soon recognized as a producer of some of the finest terra cotta manufacture in the country, and in 1878 to 1900 it produced about four tons of terra cotta per day. Why these terra cotta plants did not continue and develop with the modern terra cotta industry of the United States is not recorded. It is certain that the materials for the industry were not lacking as the terra cotta industries elsewhere are shipping their raw materials and fuel much farther

[1] Received April 7, 1921.

than would be necessary in either of these cases. The most plausible explanation is that the manufacture of terra cotta was crowded out by the great demand at that time for other ceramic wares in the manufacture of which less skilled labor was required and for which the manufacturing losses were less.

But why should Ohio not have a terra cotta industry to-day? The demand for structural material is as great as any other state in the Union can boast and yet Ohio cities must go to Indianapolis or Chicago on the west or to New York or Philadelphia on the east for the terra cotta which they use. We have Cleveland, Youngstown, Akron, Toledo, Columbus, Dayton, and Cincinnati, all cities of over 125,000 population, with about a dozen other cities of 35,000 to 75,000 population annually buying large amounts of terra cotta. And Ohio has all the essentials for a heavy clay industry. These are clay, fuel and skilled labor. Let us consider first the clay. Here Ohio excels, I believe, as we have several clay formations that are ideally suited for terra cotta. I shall mention only one which in any other state would quickly cause development of a terra cotta industry.

The Ohio Geological Survey furnishes the following information: The Tionesta or No. 3 B clay belongs to the upper part of the Pottsville formation and occurs below the Tionesta or No. 3 B coal. This is overlaid by shale or sandstone above which occurs the Brookville clay and coal which are the separating members between the Pottsville and Allegheny formations. In places the Tionesta and Brookville clays are separated only by a thin coal bed or by this and a few feet of plastic red burning shale.

This clay deposit crosses the state from Lawrence County on the south to Mahoning County on the east where it passes out into Pennsylvania. It varies somewhat in thickness and composition from place to place but in much of the area is of excellent quality. It is of best quality in Vinton, Hocking, Perry, Muskingum, Coshocton, Tuscarawas and Stark Counties. Northeast of Stark County it is so covered with glacial drift that its general character is not well known.

Occurrences

Section at McArthur, Vinton County.
McArthur Brick Company.

	Ft.	In.
Coal—*Brookville*	4	0
Clay—Dark siliceous	4	0
Shale—gray	28	0
Shale and covered	4	0
Coal—Tionesta	1	8
Clay—Tionesta, light, siliceous	4	0
Shaley sandstone (3′–7′)		

Section at Logan, Hocking County.
Logan Clay Products Co.

	Ft.	In.
Sandstone—yellow	20	0
Shale—gray	18	0
Shale—blue, fossiliferous	4	8
Limestone—very fossiliferous	0	11
Coal—Tionesta	0	6
Clay—Tionesta, dark	0	6
Clay—Tionesta, light, flinty in places	2	10
Clay—Tionesta, light, siliceous	0	6
Clay—Tionesta, light, plastic	8	8
Clay—Tionesta, light, siliceous	1	6
Sandstone, light clay bonded	20	0

Analysis of Logan Deposit

H_2O 105°	2.67
Ignition loss	9.05
SiO_2	52.29
Al_2O_3	28.38
Fe_2O_3	2.68
CaO	0.23
MgO	0.25
TiO_2	1.80
K_2O	2.07
Na_2O	0.35
MnO	trace
P_2O_4	0.06
S	0.27
Total C	0.38
Inorg. C	0.03

Section at Roseville, Muskingum County, fusion temperature cone 27–28. Chas. Drake Mine.

	Ft.	In.
Sandstone	5	0
Clay—shaley, plastic	0	11
Clay—Tionesta—dark carbonaceous	0	2
Clay—Tionesta—light plastic	5	10
Shaley sandstone		

ANALYSIS OF ROSEVILLE DEPOSIT

H_2O 105°C.	2.83
Ignition loss	6.30
SiO_2	60.00
Al_2O_3	22.37
Fe_2O_3	2.68
CaO	0.41
MgO	0.13
TiO_2	1.65
K_2O	2.59
Na_2O	0.31
MnO	0.01
P_2O_5	0.01
S	0.02
Total C	0.30
Inorg. C	0.03

Section at Ellis, Muskingum County. Fusion temperature cone 26+. Roseville Pottery Co.

	Ft.	In.
Limestone—Putnam Hill	5	7
Shale	0	6
Coal—Brookville	0	3
Clay—Brookville	2	5
Shale and shaley sandstone	3	10
Shale—soft	5	0
Clay—Tionesta—dark	0	2
Clay—Tionesta—light plastic	2	8
Clay—Tionesta—light siliceous	2	8
Shale		

ANALYSIS OF ELLIS DEPOSIT

H_2O 105°C.	2.37
Ignition loss	7.76
SiO_2	57.13
Al_2O_3	25.13
Fe_2O_3	2.11
CaO	0.28

MgO	0.11
TiO_2	1.68
K_2O	2.36
Na_2O	0.19
MnO	0.01
P_2O_5	0.03
S	trace
Total C.	0.21
Inorg. C.	0.01

Section at East Sparta, Stark County.
Federal Clay Products Co.

	Ft.	In.
Limestone—Putnam Hill	2	0
Coal—Brookville (weathered)	1	2
Clay—Brookville (upper part dark)	6	0
Shale	12	0
Coal—Tionesta (shaley)	0	2
Clay—Tionesta, light, plastic	3	0
Clay—Tionesta, quite siliceous	5	6
Shale		

ANALYSIS OF EAST SPARTA DEPOSIT

H_2O 105°C.	1.70
Ignition loss	6.37
SiO_2	61.93
Al_2O_3	21.86
Fe_2O_3	2.56
CaO	0.50
MgO	0.72
TiO_2	1.60
K_2O	2.33
Na_2O	0.17
MnO	trace
P_2O_5	0.05
S	0.01
Total C.	0.26
Inorg. C.	0.02

At Logan, this clay is used for sewer pipe and stoneware, burned at about cone 6. At Roseville, it is used extensively for stoneware and also for saggers for yellow and white ware. Fired at cone 5–6. At Zanesville, art pottery, stoneware, buff floor tile, art tile, and saggers for all these are manufactured. Fired at cone 2 to cone 8. Chemical stoneware is also made by an Akron concern.

The Wassal Fire-Clay Co., Columbus, O., used this clay from Logan for making terra cotta from 1876 to about 1888. It was considered by Dr. Orton to be of first rank as regards finish.

As regards fuel, the state of Ohio is very fortunately situated, having coal which can be obtained at very favorable prices. Oil is also as easily obtained here as anywhere in the East. Gas as a fuel is no longer obtainable for kiln firing in any pottery center.

As regards labor, Ohio should have no difficulty as she has had clayworking industries for so many years that she possesses a large class of clayworkers who are natives and would certainly furnish the men necessary to do the manual labor in a terra cotta plant. The problems of manufacture are of course different from those of other ceramic industries but not sufficiently so to minimize the value of a training in general clayworking for the future terra cotta workman. The ability to draw workmen from general clayworking plants located in the same district would be an enormous advantage in establishing a terra cotta industry.

Now to show what can be done with this single Ohio clay. We have obtained the different clays used in the manufacture of terra cotta in every portion of the United States and have found that for the bonding strength, color, low porosity and heat range the Tionesta clay gives us the equal of any mixture of clays used elsewhere. This clay burns at cone 3 to a strong body of about 8 per cent absorption and can be burned to cone 6 or 7 without material increase in shrinkage which averages about 6 per cent. The color does not change appreciably between cone 2 and cone 5 and the clay has sufficient plasticity to carry its own weight of non-plastics without serious loss of mechanical strength. In fact I have used a mixture of 40 per cent of this clay and 60 per cent of grog graded between 20 mesh and 80 mesh and produced a body of excellent strength and sufficiently smooth to take a glaze. For best results I find, however, that a body consisting of 60 per cent Tionesta clay and 40 per cent grog, finer than 20 mesh, is preferable and I have used this for general terra cotta colors and for engobe and vitreous slip studies for several years.

For this body I use an engobe consisting of:

Tennessee ball clay	15
English china clay	35
Feldspar	13
Whiting	2
Flint	35
	100
K_2CO_3	1

This engobe is applied by spraying at a weight of 22 ounces per pint.

Over this engobe the following clear glaze is placed:

0.1 K_2O	
.1 Na_2O	
.4 CaO	0.3 Al_2O_3—2.4 SiO_2
.3 ZnO	0.1 B_2O_3
.05 BaO	
.05 MgO	

Apply at 22½ ounces per pint.

This body, engobe and glaze all mature at cone 2 and do not overfire at cone 5.

A vitreous slip that worked excellently has the following composition:

Cornwall stone	40
English ball clay	18
English china clay	20
Boric acid	2
Flint	15
$CaCo_3$	2
$BaCO_3$	2
MgO	1
	100%

A STUDY OF THE OPERATION OF A DRESSLER TUNNEL KILN[1]

By Charles J. Hudson

ABSTRACT

Before installing a Dressler tunnel kiln, Norton Company made a study of an existing kiln. At Steubenville, Ohio, the kiln was found to be working well; repairs were small, economy in fuel, labor and firing time had resulted. The heat distribution was found to be variable but subject to control. The amount of rejected ware was very small and in no case could it be charged definitely to the kiln.

This kiln was investigated by the writer for a period of five weeks for the purpose of determining its desirability as an addition to the kiln equipment of Norton Company. Permission has been obtained from both the American Dressler Tunnel Kiln, Inc. and Mr. Geo. W. Cochran, Secretary and Treasurer of the Ohio Valley Clay Company to publish the results of the observations for the benefit of those who are interested in tunnel kilns.

The success of the investigation was made possible by Mr. Cochran's kindness to the writer; he was quite willing to facilitate the tests and it was a pleasure to discuss the results with him. Thanks are due him at the outset for allowing this work to be done.

General Description

There is a considerable amount of literature available relating to the principle upon which the Dressler tunnel kiln is based, notably in volumes 17 and 18, Transactions of the American Ceramic Society. A brief description of the kiln, however, may not come amiss here.

The kiln is of the muffle type. The fires are in refractory muffles on either side of a track extending the length of the

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kiln. The firing zone is about midway of the length. The ware, which is placed upon cars, is sent gradually through the kiln by means of a pushing device located at the head end; it is gradually heated by the products of combustion drawn through ducts along the kiln walls between which it passes, fully fired while passing the firing zone, cooled gradually as it approaches the exit and finally when taken from the kiln is ready to be removed from the cars.

Figure 1 is a schematic drawing of the cross section of the kiln. Combustion takes place in the double walled, trapezoidal shaped chambers on either side; these chambers are located throughout the forward end of the kiln and extend somewhat beyond the

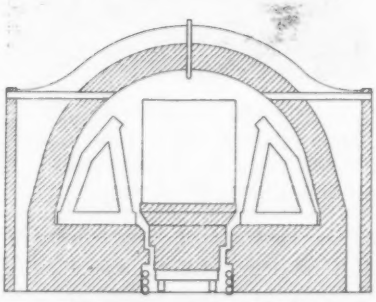

FIG. 1.—Schematic drawing of Dressler kiln through firing zone.

middle. Combustion takes place in the chambers at about the center of the kiln; the products of combustion are brought toward the forward end by means of an exhaust fan connected to the long lines of chambers on either side. Thus the chambers can be thought of as long horizontal double-walled chimneys between which the ware passes on its journey through the kiln.

The transfer of heat from the chambers to the ware probably takes place in two ways: (1) by radiation; (2) by convection currents through the channels between the inner and outer walls of the chambers. The chambers are constructed so as to allow the atmosphere of the kiln to circulate around them and yet the gases of combustion can not escape into the kiln.

After passing the soaking zone of the kiln the ware passes between pipes on either side of the kiln chamber which extend from the exit end of the kiln nearly up to the burners. Air from the kiln shed is taken into these pipes near the exit end of the kiln, brought nearly up to the burners and there exhausted outside the kiln. As the air passes through the pipes

FIG. 2.—General appearance of outside of kiln; picture taken from near exit end. Note the intake ends of the cooling pipes for one side.

it becomes heated by abstracting heat from the ware close to it. The ware, as it leaves the soaking zone, passes between these pipes relatively hot at first but much cooler toward the exit. The cooling air is always in the pipes and so does not come in contact with the ware, hence the cooling also is done by radiation and convection.

The iron framework and wheels of the cars are kept cool by the circulation of water in pipes close to these parts.

The pusher is built on the principle of a horizontal screw jack, and is motor driven. After reaching the end of its stroke either forward or back it stops automatically.

Dimensions

This kiln is about 300 feet long by about 14 feet wide at the widest part, outside dimensions. The tie rods binding the buckstays together are about 11 feet above the floor. The cross section of the kiln is such that ware can be set 48″ above the car floor and 44″ wide. The car floor is about 30″ above the track.

At the entering end of the kiln a space of about 12 feet by 6 is required for the pushing machine which moves the cars through the kiln.

Movement of Cars

Outside of the kiln, and running parallel to it, is a trace where the cars are unloaded and set. After being set they are run onto a transfer truck at the entrance of the kiln. This transfer is run into the kiln with the car on it and locked so that the car can be pushed onto the track within the kiln. Outside the kiln and in line with the track running through the kiln is the pusher, which pushes the entering car into the kiln and at the same time pushes the line of cars within the kiln ahead of it.

During the period of operation one car was put into the kiln every four hours, or six cars a day. Since the kiln held 47 cars, it required just under eight days for the cars to go completely through. The average rate of travel was 1½ feet per hour. At the same time that a car was being pushed into the kiln another car was being pushed onto a transfer at the exit end. Before another car can be put into the kiln, this car on the exit transfer must be taken out and put on the outside track.

At either end of the kiln the openings for the cars were closed by rolling metal doors; these were kept closed except when cars were either locked in or taken out. The cars were set entirely outside the kiln previous to locking in; the ware was removed from the cars not far from the exit end of the kiln at a place convenient to the warerooms.

Cars

The cars were built up on a cast iron frame each supported by four roller bearing wheels. The superstructure was made of hollow fire-clay blocks filled with Sil-O-Cel powder. The floors of the cars were made of heavy clay slabs which were directly supported by fire-clay girders. These are well shown in figures 3 and 4. The dimensions of the car floor, and thus the setting area, are 44″ by 72″. The floor is supplied with a number of holes which allow convection currents to pass through the ware and thence through the channels around the muffles.

The iron frame of the car was two inches longer than the clay superstructure. As the cars were pushed through the kiln, each pushed all the cars ahead of it by means of the iron frames. Each car was provided with a tongue on one end and groove at the other in the fire-clay piece near the bottom thus presenting a baffle for the heat, tending to keep the iron frame cooler by preventing direct radiation. The cars weigh about two tons and their setting capacity is in the neighborhood of three tons. They were numbered and always kept in numerical order, thus making it easy to locate a car in the kiln.

Outside the kiln the cars could be readily pushed by hand. When taken from the exit transfer they were pushed a short

FIG. 3.—General appearance of an empty car.

way along the outside track to the drawing locality; after drawing, the car was pushed toward the setting location which was near the forward end of the kiln. After setting the setting gang pushed the car toward the head end to await its turn into the kiln. The location of the setting position was at such a distance from the head end of the kiln that enough space was allowed for the number of set cars to last over Sunday. Similarly, at the other end, the unloading space was far enough away from the exit so as to allow space for all the cars which came out during Saturday and Sunday.

Pyrometer Equipment

A good pyrometer equipment is quite essential on any tunnel kiln. The correct temperature curve having been determined

for the ware, it is only necessary to hold the temperature constant throughout the soaking zone in order to insure proper firing. Cones cannot be used to control the burning in the way they are in a periodic kiln; they should be used frequently however, to check the firing conditions. In a periodic kiln the temperature is raised or held steady until the desired cone deformation is reached. In the tunnel it is impossible to hurry or slow up one car without doing the same to the entire train. Therefore after the kiln temperatures have been regulated so that the desired cone deformations are reached, then these temperatures should be held constant. A good pyrometer is invaluable for this purpose.

Other instruments can probably be used to good advantage on a Dressler kiln; draft gauges and combustion meters would undoubtedly prove of value. At Steubenville the kiln was provided with a pyrometer equipment and a draft gauge for obtaining the draft at different points in the combustion chambers.

Heat Distribution

At intervals throughout the length of the kiln thermocouples projecting down into the crown about 2″ were supplied for measuring the temperatures at these points; couples were also inserted into the combustion chambers, at nearly the hottest place. The temperatures at two couples in very nearly the hottest place in the crown and at one couple in the combustion chamber on either side were recorded; at all other points, seventeen in all, the temperature was indicated.

Figure 5 gives the heat curve of the kiln throughout its length. The general shape of the curve (except at station 11) is correct although the actual temperatures recorded in the soaking zone of the kiln may be in error. The temperatures were measured in most cases with a platinum-rhodium thermocouple and a Leeds and Northrup potentiometer. At a few of the stations however the kiln couples could not be readily moved in their protection tubes so the best attainable temperature as given by the couple at that point was used. All readings were corrected for cold junction temperature. Stations 16 and 17 were located in the conbustion chambers, one in either side. It will be noted

that these temperatures ran about 100° higher than the highest kiln temperature indicating good heat conducting properties of the silicon carbide chambers. Not much reliance could be placed in the reading at No. 11 station; the couple was apparently not giving truthful readings yet it could not be removed without further injury, a step which the writer could not readily undertake.

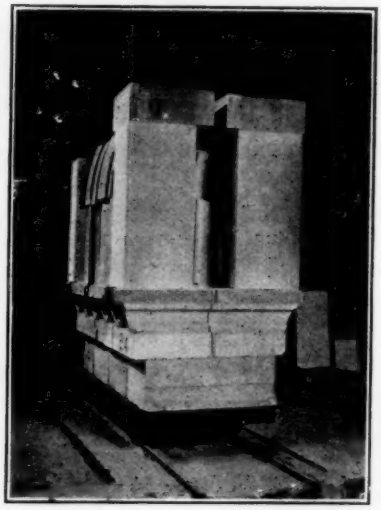

FIG. 4.—A car just out of the kiln.

The curve in figure 5 is a distance—temperature curve and should not be confused with a time-temperature curve usually given for kilns; it would become a time-temperature curve if one hour were substituted for each one and one-half feet. If the rate of travel were hastened, *i. e.*, made faster than 1½ feet per hour, the effect would be to compress this distance-temperature curve horizontally in order to obtain the time-temperature curve. This curve and the time-temperature curve coincide when the rate of travel becomes one foot per hour. During the time of observation the rate of travel was 1½ feet per hour; at intervals since then it is understood that this kiln has been run successfully as fast as two feet per hour.

TABLE OF TEMPERATURES AT THE STATIONS INDICATED ON FIGURE 2

Station	Cold junction temperatures, °C	Corrected temperatures, °C
1	25	214
2	33	385
3	30	535
4	38	765
5	40	1030
6	40	1108
7	58	1145
8	110	1199
9	136	1197
10	75	1165
11	46	585?
12	35	601
13	30	458
14	28	389
15	27	211
16	80	1299
17	70	1292

The temperature at either end of the kiln was fairly high; at the entering end it was close to 150°C, and the ware came out at 160°C. The temperature at the top of the kiln was much higher than at the floor of the car at the two ends. Although these temperatures may seem high they were not too

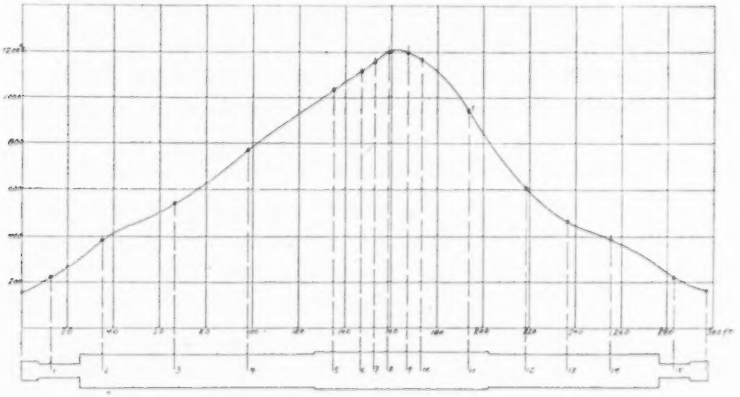

FIG. 5.—Distance-temperature curve of Dressler kiln.

high for the ware put through this kiln. A kiln constructed for ware which would not stand these entering and leaving temperatures could readily be designed.

The longitudinal temperature curve is a mechanical achievement; given the required curve through which a certain ware must pass for its proper maturity and cooling, a Dressler kiln can be constructed which will fulfill the required time-temperature requirements. The real test of a kiln of this type comes when at the same time a demand is made that the heat distribution through the cross section shall be within certain limits. Considerable time was spent in studying the cross sectional heat distribution. This was done by means of distributing pyrometric cones and Veritas discs at many points over the setting space.

The cross sectional heat distribution was found at times to be very good—less than one-third of a cone—and at other times faulty—as much as two cones difference. This may look discouraging but in reality is quite the opposite, for if the distribution had always been poor no matter how it was aided by changing setting methods then there would have been reason for lack of enthusiasm for the kiln. Since the distribution was at times very good, the problem was to find out why it was good and to try to so operate the kiln that it would always be good. The real solution turned out to be openness of setting; cars set fairly open gave good heat distribution; when set close or tight the distribution was not so good. This does not necessarily mean that cars can not be set tight with good heat distribution but it probably does mean that a good distribution can not be obtained where tightly set cars are locked into the kiln with openly set ones; a uniform setting should be adopted for best results.

The data for the heat distribution results follow: Cone pats were made up of cones 9–10–11–12. Veritas discs were usually placed with the cones.

Figure 6 shows the result of one test made over the cross section of a car; the top cone pats show cone 11 fairly well down whereas at the bottom cone 11 is only about half over. At both

the top and bottom it appears that the center was not so hot as the outsides. The figures on the discs represent the shrinkage in percentages; these vary from 8.05% to 8.45%.

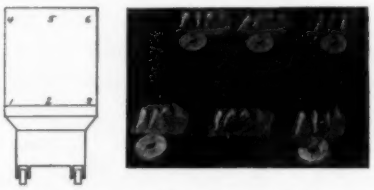

FIG. 6.—Left—Diagram showing the positions where the cones were set. Right—Cones 9, 10, 11, 12 after passing through the kiln.

Figure 7 shows the result of a second test where again the differences in cone deformation amounted to less than half a cone. There is a tendency here indicating that the car was hotter on the outside than at the center at both top and bottom.

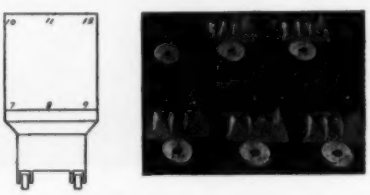

FIG. 7.—Left—Diagram showing the positions where cones were set. Right—Cones 9, 10, 11, 12 after passing through the kiln.

From the above it will be seen that the greatest difference in temperature throughout a car is as likely to be from center to outside as from top to bottom. Figure 8 illustrates a test made to see if a more open setting might improve the heat distribution from center to outside. A row of cones and discs were set across a car between flux blocks set rather openly; the floor plan is attached and shows a space of eleven inches wide extending across the car. An inspection of the cones shows only infinitesimal differences. These results are checked by the discs which show practically no differences in percentage shrinkage.

Several other tests were made which showed that the cones must be placed in relative positions in order to compare them; for example, cones exposed toward both sides and top showed a greater deformation than cones which were protected by ware from the top. This is an indication that there were convection currents moving through the muffle walls and the ware, as claimed by the American Dressler Tunnel Kiln, Inc.

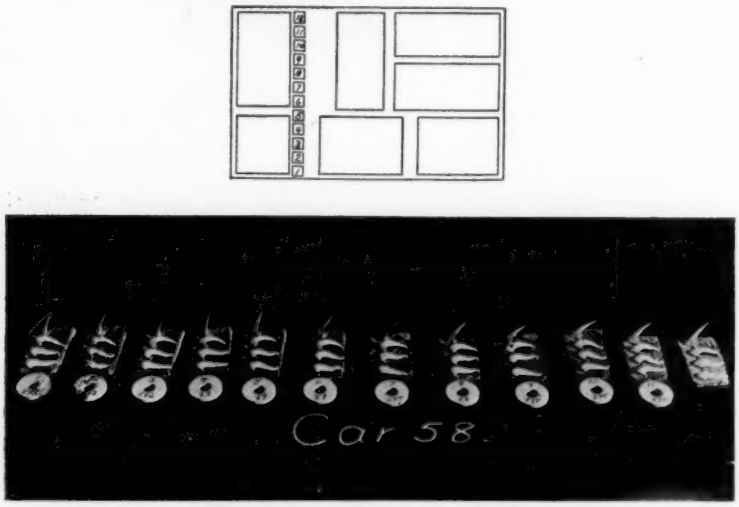

FIG. 8.—Above—Floor plan of car showing where cones were set between the ware. Below—Cones 9, 10, 11, 12 after passing through the kiln.

Defective Ware

The ware manufactured by the Ohio Valley Clay Company is glass house refractories. A large portion of the ware put through the kiln during the time of observation was rectangular shaped blocks weighing from three to seven hundred pounds; occasionally there would be set a piece weighing over a ton and often times on the same car with pieces weighing only a few pounds.

The amount of defective ware coming from the kiln was surprisingly small, and it is possible that the cause of rejection originated in the dryroom. A few pieces which were thought to

have minute cracks were marked before locking into the kiln; these always came out cracked. For this particular ware the kiln is admirably suited. No damaged ware came through during the five weeks observation, which could be definitely charged to the kiln.

Kiln Repairs

The kiln had been running about eight months at the time of observation; it was remarkably free from cracks, in fact, there were no obvious ones, but in looking for them there were found two fine hair-like cracks which were of no consequence.

During this time the cars had been without repairs. While the writer was at Steubenville three cars were repaired; a portion of the top slab was replaced on each. These were said to be the first repairs to the cars.

There is a considerable amount of mechanical equipment connected with the kiln, two fans, a water pump and the pusher, all motor driven. None of these had given the slightest trouble, yet they had seen twenty-four hour per day service since the kiln was started. Although this is a remarkable achievement for the mechanical equipment it would seem that considerable chance is being taken in operating a kiln of this sort without duplicate parts. The stoppage of the main draft fan means that the fuel supply must be immediately turned off to avoid filling the kiln shed with smoke. The cooling air fan or the water pump could not properly be down for more than an hour.

During the eight months period which the kiln had run up to the time of observation there had been one shut down of a purely accidental nature. A workman dropped a plank on the rheostat governing the motor operating the water pump; this stopped the pump and, since it ran very silently, nobody noticed that it was stopped for some time. Upon discovery of the stoppage the pump was started; in the meantime the water pipes had become quite hot and when the cold water was pumped in, the quick contraction of the pipes broke some of them allowing water to escape into the kiln chamber. In order to repair the trouble the kiln had to be partially cooled. A loss of about ten days resulted.

Fuel

The fuel used at this kiln was natural gas, which is an ideal fuel for the Dressler kiln. The amount used averaged about 73,000 cubic feet every twenty-four hours; occasionally the consumption reached 82,000 and on one day it was as low as 65,000 cubic feet. The gas pressure was held constant by regulators on the main line and also on each line running to either side of the kiln.

The reason for the wide fluctuation in gas consumption is not quite clear. Two possible reasons present themselves, changes in the B. T. U. value of the gas and improper combustion. No means of determining the B. T. U. value were available. Neither was there a means of directly determining the composition of the exhaust gases at hand, but certain fluctuations in the kiln temperatures indicated that the best combustion possible may not always have been obtained.

The temperature of the exhaust gases was about 240°C, showing that most of the heat of combustion had been given up to the ware before being exhausted out of doors.

This kiln was built with the proper facilities for burning producer gas. A gas producer was installed in close proximity to the kiln but had never been used up to the time of observation. It has recently been learned that this kiln has been run with producer gas with excellent results. The kiln is readily adaptable to either natural, city or producer gas and fuel oil.

Kiln Capacity

It is somewhat difficult to make a just comparison of kiln capacities where the wares burned are of varying types. The Dressler kiln is admirably adapted to the burning of glass house refractories where the ware possesses sufficient strength to require no saggering and its shape is well adapted to economical setting on the car tops.

At the Ohio Valley Clay Company the Dressler kiln was doing the work of nineteen periodic kilns of various sizes. Their operating time had been cut from twenty-one days to about eight days and their output had increased fifty per cent. Their gas consumption had been cut by an enormous amount and a

saving in labor of about 50% was claimed. All these claims looked entirely possible after watching the manner in which their ware was handled and comparing these methods with a mental picture of their former methods.

To express the capacity of a Dressler kiln in terms of periodic kilns, one must make an intelligent guess unless considerably more is known about the best time-temperature curve of a particular ware than can be gained by the operation of a periodic kiln. For example, we attempt to operate a periodic kiln so that all ware comes out good, the temperature rise is slow enough so as not to overheat the outside ware in the water smoking period and as a result the center ware is raised over-cautiously for we can not do otherwise; likewise in cooling we must cool for the outside ware and let the center ware take a much lower rate. In other words we are dealing with a large unit which is always at non-uniform temperatures and which must be fired over-cautiously so as to be on the safe side.

If the exact time-temperature curve by which a ware must be fired is known then, given the relative setting areas of the two kilns, it is entirely possible to express the capacity of a Dressler in terms of periodic kilns. In general, however, the temperature and safe minimum time to which a ware can be successfully fired is not known and because of this the Dressler kiln is able to cut down the time of firing in periodic kilns. Since the kiln gives practically uniform cone deformation throughout the cross section it is evident that the car rate can be started safe and then speeded up to the limit which the ware will stand. Just what ultimate rate the ware will stand must be more or less of an intelligent guess unless this rate has been determined in some other manner than in a commercial kiln, as for example in a laboratory furnace.

There is another reason which makes the time-temperature guess for ware fired in a periodic kiln still more problematical, this is the condition of the kiln atmosphere. Whether the atmosphere is oxidizing or reducing is not always known for a periodic kiln, nor is the part played by the atmosphere always known. In the Dressler kiln the atmosphere can be controlled and its effect upon the ware studied.

Taking these points into consideration the best guess we could make as to the capacity of the Dressler kiln was somewhere between five and ten periodic kilns. The periodic kilns compared are what are known as fifteen foot, down-draft, circular kilns; the setting space is about thirteen and one-half feet in diameter between bag walls and about ten feet high.

Economy

It must be readily admitted that a periodic kiln is extremely wasteful of fuel. A Dressler kiln, and probably tunnel kilns of other makes, will undoubtedly save fuel. An estimate of fifty-per cent savings is conservative.

The savings in labor by the use of a Dressler tunnel kiln, or other car tunnel kilns is somewhat problematical. At Steubenville on natural gas the care of the kiln was under one man who also had charge of the setting and drawing. At night the watchman put in a car every four hours, but was frequently at places remote from the kiln during the interim. As far as manual labor is concerned one man on a shift can take care of the kiln lock in the cars and take them out. If producer gas is used an additional man on the producer would probably be necessary.

The saving in setting and drawing labor resulting from a tunnel kiln must depend somewhat on the type of ware and the methods in use with periodic kilns.. Where large heavy pieces are fired mechanical means can be used to good advantage on the Dressler cars for both setting and drawing. The saving resulting where the ware is small and uniform in size and comes to the kiln in saggers will be less than where it is large, irregular in shape and must be packed in quartz at the kiln. The fact that all ware is set in the open at one place and drawn in the open at another should result in a saving of labor over that required for a periodic kiln because the working conditions are much more pleasant.

Additional Dressler Kilns

During the time of investigation at Steubenville advantage was taken of the opportunity to visit other plants in that vicinity where five additional Dressler kilns were seen. Although no

study was made of these kilns, conversations with the operators of them proved that they were giving entire satisfaction both in reduction in cost and in quality of ware. All of these kilns were burning natural gas although they were equipped for burning producer gas and in some cases had operated on it.

Possible Difficulties

The stopping of a Dressler kiln is of a somewhat serious nature; it causes contraction and its attendant cracking which is objectionable. The low cost of maintenance of this kiln is probably dependent upon its continuous operation. A few of the possible difficulties which may be encountered are listed here.

The combustion chambers may burn out. These should be made of the proper material to withstand the temperatures used and the action of the fuel.

Suitable fire-brick should be chosen for the crown; the weight on the crown is small but the continuous heat allows the crown to become hot throughout its thickness.

Care must be exercised in setting so that no ware will fall off a car inside the kiln. Some ware lends itself very well to stable setting; this is particularly true at the Steubenville kiln. But there are other wares which can not be set so stably, as flux blocks, and here great care must be used.

The stoppage of fans or the pump is serious but this may be eliminated by a duplicate equipment.

Advantages

The Dressler tunnel kiln can usually give a saving in firing time; this is because its cross-sectional heat distribution is practically uniform.

A saving in fuel can undoubtedly be accomplished.

Waste heat from the kiln can readily be used for heating or drying purposes.

The expense account for repairs should be small. At all plants visited where repairs had been made an accident had been the direct cause.

A muffle kiln gives better combustion control than an open-fired kiln. Where ware is usually saggered the need is elimi-

nated by the muffles in the Dressler kiln. The need for saggers for protecting the ware from discoloration is eliminated in the Dressler kiln where the fires are enclosed in muffles. The muffles may seem like needless expense where muffling of the ware is not necessary, but it is believed that better combustion control and more uniform and constant temperatures can be maintained by their use than without.

The atmospheric conditions within a kiln are often times important; some wares require an oxidizing and others a reducing atmosphere. In the Dressler kiln the atmosphere is always oxidizing unless it is made reducing by the admittance of a particular gas.

There should be a saving in breakage of kiln furniture in the tunnel over that resulting from a periodic kiln. The setting height is from one-half to one-third that of the periodic kiln, therefore there is a correspondingly lesser weight on the furniture. The uniform heating and cooling with the elimination of occasional flashing ought to prolong kiln furniture life.

Summary

The Dressler kiln was found to be giving very good satisfaction at the Ohio Valley Clay Company as well as at a number of other plants.

The cross-sectional heat distribution seems to be subject to control and differences greater than half a cone can probably be eliminated.

The control of the kiln seemed very simple, at least with natural gas.

Savings in fuel can undoubtedly be made by the use of this kiln. Savings in labor, rejected ware, kiln furniture, and kiln repairs can probably be made over those required for a periodic kiln.

A saving in firing time over that required in a periodic kiln ought to be accomplished; its amount can only be estimated. At Steubenville, the firing time had been cut to one-third the periodic kiln time.

NORTON COMPANY
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HIGH TEMPERATURE TESTING FURNACE[1]

By W. M. Hepburn

ABSTRACT

A surface combustion furnace lined with alundum and fed by seven burners supplied from a mixture box in which an explosive mix. of gas and air is made by a special inspirator melts down cone 36 in one hour using 156 cu. ft. of city gas. The max. temp., 3400°F, attained is within 200°F, of the theoretical max. Advantages claimed are: Simplicity, low fuel consumption, ease of observation and measuring temperatures and ability to produce either neutral, reducing or oxidizing atmosphere.

Introduction

The testing of refractories requiring temperatures over 3000°F has generally been regarded as beyond the gas furnace domain. The numerous possible applications for small inexpensive gas fired furnaces capable of attaining temperatures up to 3400° F should make developments along this line of particular interest.

A study of the conditions to be considered in producing these temperatures in a gas furnace is necessarily closely connected with the maximum temperature obtainable for any particular gas fuel, that is, the so-called flame temperature. Flame temperature occupies a rather indefinite position and is only obtained by theoretical calculations. These calculations show that combustion of average city gas with cold air is capable of producing a temperature of approximately 3600°F. The question of greatest importance, however, is how nearly can this temperature actually be realized at some useful point?

Gas fired crucible furnaces which have at various times been constructed for this type of work may be listed in 3 classes. One of each of these classes was constructed and comparative tests run to determine the maximum possible temperature attainable inside a container. The three classes together with the average maximum temperature obtained with each class are as follows:

[1] Received May 16, 1921.

1. The gas mixture is supplied tangentially, combustion taking place against the furnace lining. Max. *t.*, 3100°F.

2. The flame envelops the crucible upon which it is concentrated by various baffle arrangements. Max. *t.*, 3200°F.

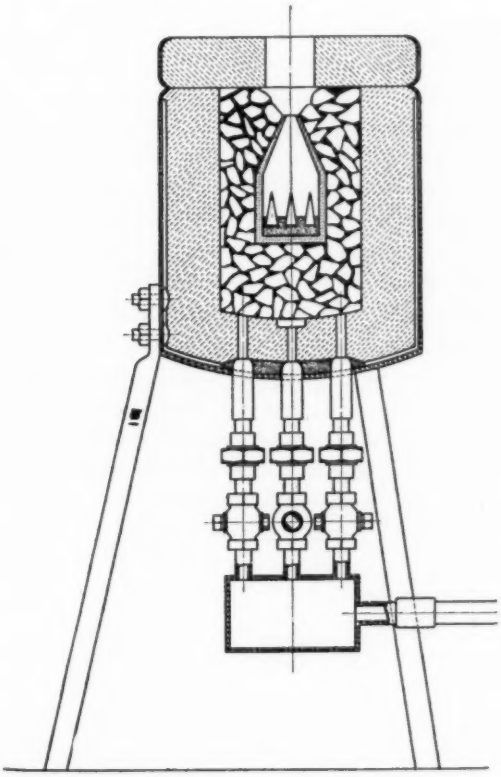
3. Surface combustion type. Max. *t.*, 3400°F.

As this article is intended to deal more with practical results than with theories pertaining thereto, no attempt will be made to account for the difference in these temperature limits other than to say that the basic idea of the original surface combustion as invented by Prof. Bone and Dr. Lucke was to burn an explosive mixture of gas and air inside the pores of some refractory material. This method produces a maximum amount of radiant heat, and the resulting light wave energy greatly accelerates the chemical reaction of the gas mixture. The above tests show that it is possible by the use of these principles to attain a temperature within 200° of the theoretical maximum.

Description of the Furnace

The construction of the furnace in which these results were obtained is shown in the accompanying illustration. The furnace consists of a heavy cylindrical metal casing lined with a special alundum mixture the fusion point of which is approximately 3500°F. The cover consists of the same refractory material. Gas and air mixed in an inspirator of a special design built inside of a tee are fed to the mixture box. From the mixture box the explosive mixture is delivered by 7 pipes to corresponding burners, each pipe being provided with a cock. The receptacle in which the test pieces are placed consists of an alumina crucible two inches in diameter capable of accommodating 5 one-inch Seger cones or test pieces. This crucible is placed in and supported by the refractory material. This refractory is of the same material as that used for the lining but in lump form.

A small size lump checks the flow of the gas, while a coarser one gives less resistance to the flow. The temperature limits of the furnace are very sensitive to the selection of the proper size refractory. The selection now used when properly filled in and with a mixture pressure of twelve inches on 7 burners melts down cone 36 within an hour, consuming 156 cu. ft. of city gas.



A funnel-shaped cover with an opening at the top for observation is placed over the crucible containing the test cones. This cover is so designed as to enable all parts inside of the crucible to be observed at any time during the operation thereby enabling the temperature readings to be taken with optical pyrometers.

Procedure for Determining Fusion Points of Test Pieces

In making standard fusion tests a very gradual rate of heating is required. Therefore the furnace is usually started with only one central burner open at some low mixture pressure. As the furnace begins to heat up two opposite outside burners are opened up, then two more and so on until all 7 burners are opened. Further increase of temperature can be attained by

increasing the mixture pressure. Due to the use of 7 burners and the possibility of wide range in mixture pressures any amount of gas between 6.5 and 160 cu. ft. can be burned per hour. Increasing the gas rate beyond this point has no effect on the temperature

If desired, high temperatures can be obtained within half an hour, starting with a cold furnace. These sudden rises in temperature, however, are detrimental to the lining.

The samples of clay to be tested are given the same shape and size as small Seger cones. The cones are fastened on the bottom of the crucible with moistened white alundum cement or powdered alumina which has been burned at high temperature. Thus for instance a cone of clay and 4 Seger cones are fixed in the crucible. The temperature of the furnace is increased, observations being made from time to time. At the point where the test piece sags over, the gas is shut off and the furnace allowed to cool sufficiently to permit the removal of the crucible. The condition of the accompanying Seger cones will indicate the fusion point of the test pieces with a degree of accuracy dependent upon the difference between the fusion points of the Seger cones selected. Sufficient air under 3 lbs. pressure must be available. If an individual blower is used in connection with the furnace it is an advantage to bypass the excess air of the blower and by regulating the bypass, control the air pressure at the furnace. To enable observation from short distances the flame issuing from the top opening is blown to one side by an air blast thereby permitting the observer to approach to within 10 inches of the top of the furnace.

Some of the important advantages of this type of furnace are namely: Simplicity, low fuel consumption, ease of observation and measuring temperatures and ability to produce either a neutral, reducing or oxidizing atmosphere. In this way the test cone can be subjected to conditions identical with those under which the material is to be used. Carbon or graphite resistance furnaces usually used for this type of work have a strongly reducing action on clay, which action influences the melting point by reducing the iron oxide and producing other complex reactions.

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REFRACTORIES UNDER LOAD CONDITIONS[1]

By H. J. Knollman

ABSTRACT

Life factors.—The life of fire clay slabs, rings and saggers is influenced by a number of factors, both mechanical and chemical. The chief factors controlling the life of the slabs are (1) proper selections of clays and grog, (2) medium absorption or porosity, (3) strength in the unburned state, (4) proper and thorough blending and preparation of the mix, (5) proper pressing so as to insure freedom from flaws, (6) proper drying, (7) proper setting in the kilns and especially (8) initial burn. These factors are briefly discussed.

Setting.—The manner of setting grinding wheels, using large slabs is described. This manner of setting causes transverse bending stress to be set up in the slab and shear stresses to develop. This shearing force, in connection with the large size and the high temperature (cones 11 to 12), make severe conditions for the slab to withstand.

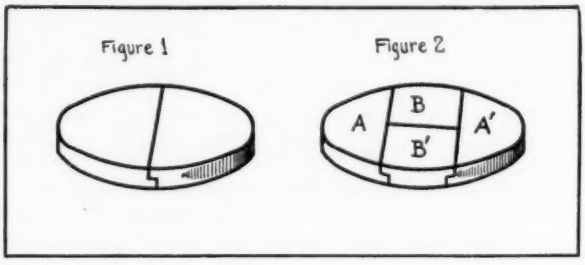
Shape and size.—The rate of heating and the size and shape of the slabs are additional factors. Round slabs, up to about 20″ in diameter have a decidedly longer life when made in two half sections as compared with the solid shape. Larger slabs have longest life when split up into four sections, while if solid they will fail in one burn. Warping of the slabs, as well as cracking, causes failure. In general, if the width of area of the load is held constant, and length of span of the slab is increased, deformation and cracking is slightly increased. If the span is held constant, and the width or load area is increased warpage is greatly increased, especially as the number of burns under load increases. Cracking also increases in direct proportion to increase in width. These features are more pronounced the longer the span.

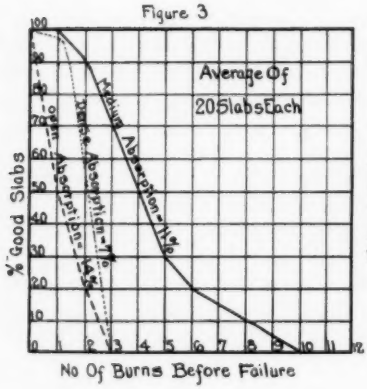
Ultimate failure at high temperatures.—When not due to structural defects, failure is brought about by a gradual decrease in mechanical strength from burn to burn, so that fire-clay slabs under transverse load at such temperatures have decided limitations.

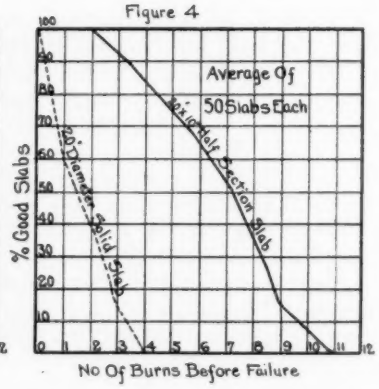
The ability of fire-clay slabs, rings and saggers to carry load at elevated temperatures is one of importance and concern to many clay working industries, but probably in no industry is it of such vital concern as in the abrasive or grinding wheel industry. This is due not only to the fact that the refractories are called upon to carry heavy loads under rigid conditions, but also because of the large sizes of slabs involved as well as the comparatively high temperatures to which they are subjected.

[1] Received April 16, 1921.

Since grinding wheels varying from a fraction of an inch to 30 inches in diameter are manufactured, slabs to support them in the kiln must necessarily vary similarly in diameter. It is, therefore, customary to use saggers or solid one-piece round slabs up to about 20 inches in diameter for the smaller wheels. The larger sizes are made more economically and are more readily handled if subdivided into two or more sections. Intermediate sizes are, therefore, customarily made in half sections with a ship-lap joint as in figure 1, while the larger sizes are conveniently made in quarter sections as in figure 2.







One of the prime requisites is that of strength in the raw unburned state. With individual slabs weighing from a few pounds up to 150 pounds, the strength in the raw state must be sufficiently great to prevent undue breakage or cracking before the slabs are burned.

The selection of the individual clays and their proper proportions are of no greater importance than the control of the manufacture of the slabs themselves. In fact, experience has demonstrated that the selection of the fire-clays, as long as they are good clays within a safe field of usefulness, is not so important as close attention to the various details in the manufacture. While the usual laboratory tests for shrinkage, warpage, transverse strength, absorption, porosity, et cetera, form valuable guides, the selection of the clays is, however, based primarily upon compromise between these different properties, the undesirable as well as the desirable ones.

All other factors being constant, a slab which is tight and dense, no matter how strong it may be, will, under load, have a short life, owing to its inability to withstand the strains incident to the repeated heating and cooling. A slab which is too open, on the other hand, will be weak and fragile and will not be able to stand either the weight of the load or the strain to which it is subjected. A fairly large field of intermediate density gives slabs which have sufficient strength and hardness to sustain heavy loads and are also porous and open enough to stand volume changes and warpage strains under repeated heatings and coolings.

Figure 3 shows the relation between number of burns before failure and per cent of "goods" for three types of slabs similar in all respects, except that the absorptions were varied by changing the relative proportions of tight and open burning clays going into the mix. Although the degree of vitrification of these clays enters in as a factor, it is slight as compared with variation in degree of openness.

Both the very open slabs and the very dense slabs failed to the extent of 100 per cent in 3 burns at cone 11. The medium porous slabs (10 to 11 per cent absorption), deteriorated much more gradually under the same conditions, the last slab failing in the 10th burn. In fact, a certain amount of strength in the burned state is sacrificed in order that the slabs may be sufficiently open.

The shrinkage of the various clays used is of importance, not only in governing the dimensions of the slabs, but also as a

factor in determining their mechanical strength. The quantity of high shrinkage clays in a mix may be carried to a point where the clay portion will shrink away from the grog to such an extent as to form numerous fine cracks between the grog and clay portion throughout the slab. Outward manifestations of this condition are frequently observed in saggers which have numerous fine hair cracks on their surfaces. The greater the proportion of highly shrinking clays used, the more pronounced does this condition become, and when carried to excess, the slab becomes distinctly lower in mechanical strength. This, therefore, very largely offsets the advantages to be derived from the elimination of low shrinking, high sandy clays, with their attendant volume changes.

The size of grog used in the mix also affects the load-carrying capacity. For slabs which are to carry heavy loads, especially those subject to severe transverse bending, coarse grog is necessary to help keep the body sufficiently open, as well as to prevent excessive shrinkage and cracking. Grog, about 4 mesh to 20 mesh in size, is used to the amount of 50% and all fines are eliminated. Even a small amount of fines in the regular slab mix has a noticeable detrimental effect on the life of the slab. But where the refractories are merely under compression, as in the case of the rings used to support the slabs in a stand, fine grog gives additional strength and is there used to advantage.

Having made a proper selection of clays, usually about 50 per cent plastic tight burning clays, and 50 per cent less plastic open burning ones, it becomes important to secure an intimate mixture. Unquestionably the dry or wet pan gives the best results. Where the ordinary soaking pit method is used, sufficient time must be given for the slaking down of the clays in water and to insure a certain degree of softening in the case of some clays. Thorough pugging of the clay mix is then very necessary. As long as lumps or particles, even though small, of the individual clays used can be distinguished in the mix, the grinding and preparations of the mix are not complete or satisfactory.

The density of the prepared clay mix ready for pressing is also a point to be considered. This density is largely controlled

by the amount of water used in tempering, mixing and pugging. The denser and more compact the structure of the mixture, provided it is not too dry, the harder will be the burned refractory made from it. If too dry, the individual lumps used to make the slab will not press and knit together properly. A mix which is too wet, on the other hand, will not give as dense a structure and as compact a slab as one of proper working consistency.

Pressing of the slabs, especially the larger sizes, is an important operation. Care, and some skill and strength on the part of the presser are necessary to produce a slab free from internal flaws. These flaws are mainly of two types, (1) the more or less long narrow crack within the interior of the slab, sometimes quite wide and not visible from the outside; and (2) holes of varying size or round smooth depressions within the interior of the slab sometimes having small radial cracks leading from them. These flaws are caused by the failure of two or more lumps of clay to become perfectly welded and knitted together when pressed in the mold. The individual pieces of clay remain to an extent. Best practice requires that a lump of clay large enough to approximately fill the mold be used, while exerting a harder pressure also helps.

The dried green slabs, preparatory to the initial burn, must be set in the kiln as tightly and closely together as possible. If they are set even slightly loose and irregularly, they will upon contraction during the burn warp out of shape, which generally renders them unsuitable for further use. Overburning will tend to produce the same undesirable result. Where they are set so as to reinforce each other, contraction will be uniform over their entire area and warping will be prevented. The necessity of having all slabs and saggers perfectly dry before they go to the kiln for the initial burn is obvious, as is also the necessity for a slow water smoking period.

The heat treatment to which the slabs are subjected is of paramount importance, probably more so than any other single operation. Every clay mix has a definite distinct temperature at which maximum strength is developed which in turn largely governs its load carrying ability and maximum service. Slabs requiring a heat in the original burn a few cones higher than

they are to be subjected to later have a longer life than those requiring the same heat for proper maturity. The former are less subject to warping and deformation under load.

Table 1 gives the results of a study made on slabs, free from cracks, of the same dimensions and composition, which were given the heat treatments indicated. The 14 slabs were burned to cone 12 half down to down. The 20 slabs were burned from cone 13 bent to about half down, while the 34 slabs were

TABLE 1

No. of slabs	Initial burn cone	Per cent with no cracks	Per cent slightly cracked	Per cent badly cracked	Per cent broken
14	12	0	21	29	50
20	13—	15	40	35	19
34	13+	38	44	15	3
53	14	68	24	4	4

burned at cone 13 three quarters down to 14 well bent. The 53 slabs were burned to cone 14 down, the temperature required for proper vitrification and best maturity for this particular composition. These temperatures, while not exact, do represent distinct differences in the final heats obtained and the slabs show definite differences in hardness, appearance, etc.

They were then used with loads consisting of regular grinding wheels. Those under the "No cracks" column came out of the kiln with no signs of a crack whatever. "Slightly cracked" slabs were those having a relatively short fine crack, very short large crack or a long very fine crack after drawing from the kiln. These types of cracks in general are not serious enough to cause the slab to break in the succeeding burn. "Badly cracked" slabs are those with a long large crack which generally causes breakage of the slab in question in the following burn.

These results showed conclusively that the initial burning of the slabs is very important and has considerable influence upon their life. Those burned to cone 12 were soft and underburned and can be safely counted upon to last only one burn. Those burned to cone 13 not more than half way down are quite better, although nearly 50 per cent are badly cracked or broken. Those burned to cone 13+ showed still greater improvement, while those burned to cone 14 down showed up very well, only 8 per cent being badly cracked or broken.

Some of the same slabs after close observation and recording of their condition were again placed under regular load, and upon being drawn were re-examined in order to trace the progress in cracking. These results are given in Table II.

TABLE II

	Cone 13— slabs, per cent	Cone 13+ slabs, per cent	Cone 14 slabs, per cent
Crack same as before.....	0	12	54
Increased width of crack.....	55	40	15
Increased length of crack....	31	10	12
New cracks developed.....	14	38	19
Total number of cracks.....	42	40	41

Here again is shown in a striking manner the difference between a well burned slab and one slightly less well burned. Those burned at cone 12 were so poor that it was useless to test them in a second burn. Those at cone 13—, while not appreciably underburned, according to appearance, showed that every slab tested increased in either the width or length of crack. Those at cone 13+ showed that but one out of eight cracks did not increase in width or length and generally the increased length and width of crack was particularly marked. The slabs burned at cone 14 down, on the other hand, showed over 50 per cent remaining in the original condition. Although the cone 13— slabs do not show up newly developed cracks as strongly as the cone 13+ and cone 14 slabs, this is in reality due to the fact that the cracks previously present increased to such an extent as to make it unnecessary for new cracks to develop.

Slabs slightly overfired have a longer life than underfired ones, but not as long as the best. This is largely due to the fact that such slabs are generally slightly warped. The initial burn is, therefore, not only very important but is entirely independent of the subsequent heats to which they are subjected. The practice, so often prevalent, of putting green slabs in odd places in the kiln containing regular ware, where they generally receive the greatest or else the least heat is poor practice. Likewise, the tendency to burn a kiln full of green slabs in a careless manner is just as detrimental to best results.

In setting the kilns with wheels, it is necessary that the bottom slabs be supported upon a firm foundation, consisting of

brick piers at frequent intervals. A thin layer of sand is then spread uniformly over the surface of these bottom slabs. Fireclay rings are then set around and near the periphery of the slabs, and the grinding wheel is set directly in the center. In the majority of cases, coarse sand is placed between the wheel and the ring, and sometimes the wheel is firmly imbedded in the coarse sand. Another set of slabs is then placed upon the rings, clay wads separating them. A layer of sand, an abrasive wheel in the center and rings on the outside are placed as before, the rings being placed directly in line with rings underneath. This process is repeated for the entire height of the stand.

It will be seen from the manner of setting that the slabs are in compression only at the points where the upper and lower rings are superimposed upon each other, together with the section of the slab between them. The rings together with this small cross section in compression, therefore, carry the weight of all the layers above, whether this weight is that of a dozen or more layers near the bottom or only one set at the top. Since fire clay refractories are able to withstand high compressive forces, as compared to transverse stresses, the refractories seldom, if ever, fail from this source. Each slab or set of slabs, on the other hand, carries the weight of the wheel and its quota of sand, and the greater part of this weight is concentrated toward the center. Since the abrasive wheel occupies the center portion of the stand, no supports of any kind can be placed under the slabs to support them, or to relieve the transverse bending effect. The load applied in the center of the stand, therefore, acts as a shearing force, and a shear is developed when the slab fails. They are all subjected to the same conditions with the exception of the bottom slabs, which are well supported over practically their entire area, and those used on the top of the stand, which carry no load. It is a matter of experience that cracked and warped slabs occur anywhere in the stand, towards the top in about the same ratio as in the center or bottom of the stand, with the exceptions noted.

Since a temperature of cone 11 to 12 is required for the burning of grinding wheels, the slabs are subjected to severe heat treatment in addition to rigid load conditions. A gradual

softening then takes place, as evidenced by warping of slabs of long span, and the mechanical strength is lowered. That increases in temperature have a marked influence on the life of the slab is beyond question. The scrap pile is always larger if the kiln has been burned to cone 12 as compared with cone 11. A quick burn as compared with a slower one to the same temperature also rapidly increases breakage, which is likewise the case with rapid cooling. Warping, cracking and decrease in strength are all increased at a very rapid rate if the burn is conducted under reducing instead of oxidizing conditions.

The smaller slabs are made round and solid, but a point is soon reached where it is more economical to split them into two sections, not only because of increased ease in manufacture and handling, but also because of the increased life. Figure 4, for example, illustrates the relative life of a solid one piece slab of about 20″ in diameter compared with that of half-section slabs made as shown in figure 1. Each half section, being in effect a semi-circular slab, then has a greatest length of 20 inches and a maximum width of 10 inches. These slabs were subjected to the same conditions throughout.

It will be seen that the solid slabs cracked excessively under load conditions and that the breakage was very high from the start, all failing in 4 burns. The half-section slabs on the other hand, did not fail at all for a few burns then a gradual failure set in and after several burns the rate of failure increased rapidly. The last half-section slabs to fail did not do so until the 11th burn. The outstanding difficulty with the solid slab is that it generally develops a long crack somewhere towards the center, which frequently divides it into two sections. In doing so, however, it develops additional radial cracks, which soon cause it to break into 3 or more pieces, when it is worthless for further use. When half sections are used the slab not only may be regarded as already being cracked in two pieces, but there is also a decidedly less pronounced tendency for radial cracks to develop, since there is some elasticity in a two-section slab while it is being subjected to expansion and contraction strains, which is not possible in a solid slab.

As the diameter of the stand increases, the dimensions of the

two-section slabs increase accordingly. The maximum length and the maximum width of the semi-circular slabs increase in the definite ratio of 2 to 1, but the effect of these increases upon the tendency to fail is not in a like ratio. A definite slight increase in width plays a greater part in tendency to failure under load than the corresponding double increase in length. This is partly due to the fact that larger, heavier wheels are placed upon the larger slabs, thus increasing the load, but it is due to a far greater degree to the larger area subjected to the load. In general, the wider the semi-circular slab becomes, the greater the tendency to failure from cracking. If carried far enough, these semi-circular slabs become so large that they in turn will crack excessively in one burn and all will fail in a few additional burns.

Because of this and the greater ease of handling, et cetera, the larger slabs are subdivided into four sections as shown in figure 2. A slab, 30″ in diameter, for example, if made solid will, regardless of the thickness, not last more than the first burn under load. Indeed, it will crack excessively and in most cases fail, merely under its own weight. If made in two sections, each section has a short life before failure. If made in four sections, however, each section will have a comparatively long life.

Failure, besides taking place through the development of cracks, is also brought about through warping of the refractories. The warping tendency is greatly increased by transverse bending loads, and is always present. In the smaller two section slabs, it is not very pronounced, not only because they are frequently reversed, if they are but slightly warped in one direction, but also because the span is not large. In the large four-section slabs, however, this factor becomes very prominent. The side pieces AA′ of figure 2 are especially subject to deformation, because of their long span, since their length is great compared to the width. The superimposed weight on the slab is also unequally distributed, since it is centered in the middle over a comparatively small area. The center pieces BB′ are not subject to this deformation in a like degree, since their span is much shorter and the weight of the abrasive wheel upon them is distributed over the greater portion of their area. They would be subject to just as severe a deformation if they were made

as one long center piece across the entire span, but when made as two center pieces BB′, they may be regarded as a long center piece already cracked in the middle, so that the warping and cracking tendencies are very materially reduced.

Just as the rate of failure of the half-section slab is increased as the width of the slab increases, so also does this rate increase as the width of the four-section slab increases. This holds true of both the side and center pieces, although the manner of failure is somewhat different, in that warpage or deformation is pronounced in the side pieces, but not in the center pieces.

If the width of the side pieces is held the same and their length or span is increased, deformation and consequent failure is increased in proportion to the increased span. If the span is held constant, and the width, and incidentally the area of the load is increased, warpage of the slabs is very greatly increased. This deformation in general, however, does not take place in the first load burn, but is a gradual accumulation of successive burns, the degree of warpage increasing at a much faster rate in the wider slabs than in the narrower ones. The narrow side piece slabs do not warp to any great extent, even after a number of burns, but will fail from cracking in much the same way as do the smaller half sections. The wide side piece slabs, on the other hand, warp at first very gradually, almost imperceptibly, and then more rapidly. Their load conditions are most severe because in addition to their span, they also are called upon to hold up in place the center pieces with their superimposed loads.

The center pieces have a longer life, since their load is distributed over the greater portion of their area, so that the condition approaches more nearly that of compression, especially in the smaller sizes. In fact the breakage of the smaller sizes is slight, so that they have an almost indefinite life. As the dimensions increase, however, failure increases proportionally. As long as the span between the side pieces does not become great, they will generally fail across or parallel to the width. When the span becomes large, however, the greater proportion crack lengthwise, *i.e.*, perpendicular to the span. If the center pieces become very large, they will fail at a comparatively fast rate, much the same as wide half-section slabs.

The thickness of the slabs plays a rather unimportant part. If they are too thin, they will be too weak to carry heavy loads and to stand any rough handling. Too thick a slab, however, not only requires excess clay, but cracking is increased.

That volume changes play an important part in the deterioration of all slabs is evidenced by the fact that those that have failed after several burns generally exhibit numerous fine cracks, where the clay matrix has shrunk away from the grog. Where the load conditions are such that warping and cracking do not readily take place, the slabs do not give much evidence of this, although such volume changes must have taken place to a lesser extent. That failure in general is due to a combination of causes is seen in the fact that there is no great uniformity in the life of slabs, made of the same mix, in the same way, and subjected to the same size and manner of load. Some will outlive their mates by several burns.

In general, then, in tracing the progress of deterioration of slabs under load at high temperatures, the first slabs to fail are those structurally defective, that is, those having flaws, laminations, et cetera. Then there is a gradual decrease in mechanical strength, due to physical and chemical changes taking place in successive burns, until the point of failure is reached, which in turn is largely influenced by the relation of the load to the strength and position of the refractory. But after all, fire-clay refractories have decided limitations under the conditions given, so that the need of "superior refractories" having constancy of volume, high mechanical strength, ability to carry load at high temperatures, and to withstand sudden temperature changes and which are economical at the same time, is very apparent.

ABRASIVE COMPANY
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CERAMIC ABSTRACTS

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[1] The abbreviation (*C. A.*) at the end of an abstract, etc., indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. Recent progress of the ceramic industry. KIYOHARU KONDŌ. *J. Chem. Ind.* (Japan), **23,** 764–75(1920).—Progress of this industry in Japan is represented by incorporation of 107 new manufg. houses in 1919. Past and present activities are discussed for manufg. of bricks, pipes, tiles, fireproof utensils, china ware and other porcelain, glass, for plate and bottle, silicate glass, elec. globes, and cements. S. T. (*C. A.*)

2. Industrial tuberculosis and the control of the factory dust problem. C. E. A. WINSLOW AND LEONARD GREENBURG. *J. Ind. Hyg.*, **2,** 333–43, 878–95(1921).—A critical study with bibliography. The first installment is devoted essentially to the relation between industrial dusts and respiratory disease. The second installment contains sections on: method of studying dust content of air, variations in dust content of air from normal and industrial environments, control of dust hazard (by substitution of wet for dry processes, by conduct of dust-producing operations in enclosed chambers, by operation of hoods and local exhaust ventilation, by wearing of respirators and helmets), importance of definite analytical standards in control of industrial dust hazards. JOSEPH S. HEPBURN (*C. A.*)

3. Investigations of the chemical literature. FRANK E. BARROWS. *Chem. Met. Eng.*, **24,** 423–8, 477–9, 517–21(1921).—A valuable general survey of methods and facilities. Library facilities, general reference books, the periodical literature, indexes, patents, etc., are discussed. The importance of proper training and guidance in making investigations of the chemical literature is emphasized. E. J. C. (*C. A.*)

4. The future of ceramic education in America. EDWARD ORTON, JR. *The New Jersey Ceramist,* **1,** 8(1921).—The author reviews briefly the diff. systems of ceramic education which are in effect throughout the world.

He then discusses the American system of education in ceramics, its history and the results. He states that the pottery industry has been the most reluctant to accept the young graduate and gives the following reasons: 1—The unionized closed shop; 2—The influence of the conservatism of the English potters and their successors; 3—A mistaken notion of self sufficiency and superiority on the part of the potter.

The author is of the opinion that thus far the trade school training in this country has failed to play an important part in our educational system because of peculiar psychological conditions which prevail and consequently, if American potters wish to develop trade schools, they must adopt entirely different measures from those which have been tried. Attempts to combine or to associate closely the trade school and the technical school will fail.

C. W. PARMELEE

PATENTS

5. Method for handling bricks. JAMES B. LADD. U. S. 1,373,513, April 5, 1921. The method of handling bricks which consists in forming stacked units with the top course arranged to form parallel channels, the chan-

nel forming bricks suitably spaced to form a support for a similar superimposed unit and at the same time to povide recesses for receiving lifting elements beneath the superimposed unit resting upon the channel forming layer, and for permitting the withdrawal of the elements therefrom, and translating the stacked unit by inserting the lifting elements into the channels beneath the unit and moving same.

6. Clay Press. RALPH F. MEYER. U. S. 1,373,903, April 5, 1921. In a clay press, the combination with a die member, of a hollow mold adapted to contain plastic material and coöperating with the die member for forming a longitudinal opening in the plastic material, means for moving the mold toward and away from the die member, a plunger movable toward and away from the interior of the mold, and automatically actuated means for reciprocating the plunger.

7. Process and apparatus for drying crucibles. LOUIS VERGNIAUD, Paris, France. U. S. 1,373,688, April 5, 1921. A process for drying crucibles consisting in placing the crucibles in inverted position on a heated surface, subjecting the interior of the crucibles directly to a continuous circulation of hot air, and the exterior to the heat given off by the heated surface.

C. M. SAEGER, JR.

Apparatus and Appliances

8. Indicators for carbon dioxide and oxygen in air and flue gas. L. H. MILLIGAN, D. O. CRITES AND W. S. WILSON. Bur. of Mines, *Tech. Paper* **238**, 23 pp.(1920).—Construction and operation are described of portable instruments designed in the research lab. of the Pittsburgh expr. station. CO_2 is absorbed by NaOH; O is absorbed by alk. pyrogallate. For details see the original. JEROME ALEXANDER (*C. A.*)

Refractories and Furnaces

9. New German refractory product. ANON. *Chem. Met. Eng.*, **24**, 1070.—A new method of making firebrick more refractory has been perfected in Germany, consisting of a coating comprising a mixture of 75 per cent carborundum and 25 per cent sodium silicate. The mixture is applied to the bricks when they are thoroughly dried, and the coating sets and thoroughly dries in twenty-four hours, being slowly heated and burned in. This coating averages about one-fiftieth of an inch in thickness, and the adherent glassy veneer of carborundum gives remarkable resistance to any mechanical injury. It is claimed to withstand very high and rapidly varying temps. and affords complete protection against the chemical action of flames. This coating has been used successfully as a lining for gas retorts as well as for the outside surface. A paste of equal parts of carborundum and clay is used for repairs when cracks occur. H. F. S.

10. The outlook for the magnesite industry. ANON. *J. Elec. West Ind.*, **46**, 245–6(1921), 2 illus.—Extensive deposits of cryst. magnesite occur in Stevens Co., about 60 miles from Spokane, Wash. American interests

control approx. 80% of the magnesite deposits of the world. The daily consumption of plastic magnesite in the U. S. is about 100 tons; it is used in a cement which has enduring qualities and sets speedily. C. G. F. (*C. A.*)

11. Tentative method for ultimate chemical analysis of chrome ores and chrome brick. ANON. *Proc. Am. Soc. Testing Materials*, **20**, I, 647–51(1920). —*1. General method.* Dry the fine powder at 110° for not less than 1 hr. Cool in a desiccator. Fuse 0.5 g. of the sample with approx. 10 g. of fused $KHSO_4$ in a Pt crucible. The most refractory ores should be thoroughly fused in 1½–2 hrs. Allow the crucible to cool in the air and dissolve the fusion in 200 cc. hot HCl (1:1), boiling until the soln. acquires a clear green color. Evap. to dryness on a water bath and bake at exactly 120° until free from HCl fumes. Moisten with hot HCl (1:1), evap., and bake as before. Dissolve in 200 cc. hot dil. HCl and filter SiO_2. Ignite and weigh the SiO_2, detg. the SiO_2 by treatment with HF and H_2SO_4. Any appreciable residue should be fused with $KHSO_4$ and added to the filtrate. Dil. the filtrate to 500 cc. and ppt. Fe, Al, Cr and Ti with NH_4OH in very slight excess. Filter, dissolve in HCl and reppt. Again filter the combined hydroxides and dissolve in HNO_3. Evap. in a casserole adding crystals of $KClO_3$ from time to time until the Cr is completely oxidized. Dil. with hot H_2O and again ppt. with NH_4OH, filtering as before. Repeat the oxidation 2 or 3 times until the filtrate shows no further traces of Cr. Combine the filtrates and evap. to 500 cc. Add H_2SO_3 until the soln. changes to a brilliant green color and heat to boiling. Add a very slight excess of NH_4OH, filter, wash, ignite, and weigh as Cr_2O_3. The hydroxides of Fe, Al and Ti are ignited and weighed. Fuse the combined oxides with a small amt. of $KHSO_4$, dissolve the fusion in dil. H_2SO_4, reduce with H_2S and titrate with $KMnO_4$. Det. the Ti colorimetrically and calc. the Al by difference. To the combined filtrates from the hydroxide pptn. add Br, allow to stand a few min. and then add sufficient NH_4OH to ppt. the Mn. Boil, filter, ignite, and weigh as Mn_3O_4. From the filtrate ppt. the Ca with NH_4OH and $(NH_4)C_2O_4$ and det. in the usual way either by ignition to the oxide or by titrating with $KMnO_4$. Det. the Mg in the filtrate from the Ca ppt. in the usual way as $Mg_2P_2O_7$, and use the J. Lawrence Smith method for the detn. of alkalies. *2. Rapid routine method.* Fuse 0.5 g. of the fine dry sample with 8–10 g. of Na_2O_2 in a Ni or porcelain crucible. Leach out with cold H_2O, boil 15 min., cool, and add 100 cc. H_2SO_4 (1:1). Cool, and titrate the Cr with ferrous soln. and $KMnO_4$. To detn. Si and Fe, fuse 0.5 g. of the sample in a Ni crucible, leach out with cold H_2O, acidify with HCl and evap. to dryness. Take up with 200 cc. of H_2O and add 10 cc. HCl. Filter SiO_2 and if necessary repeat the evapn. and filtration. Make the filtrate alk. with NaOH and add 5 cc. Br. Digest ½ hr. on a steam bath. Filter $Fe(OH)_3$ on asbestos, dissolve and reppt. Filter again, dissolve in hot HCl, reduce with $SnCl_2$ and titrate with $KMnO_4$ in the usual way.

S. G. SIMPSON (*C. A.*)

12. The importance of air supply in combustion of coal. HENRY KREISINGER. *New Jersey Ceramist*, **1**, 39 (1921).—A general discussion of the

processes of combustion and their control in the operation of hand fired furnaces. About 14 pounds of air must be supplied to each pound of bituminous coal burned. This includes from 25% to 50% excess over the theoretical quantity but it is necessary to obtain nearly complete combustion in commercial furnaces. In hand fired furnaces if the fuel bed is 5 to 6 in. thick, only 6 or 7 pounds of air to a pound of coal can be supplied through the grate; the other 7 pounds must be supplied over the fuel bed. If larger quantities of air are forced through the grate the rate of combustion is increased but the same proportionate amount of fuel is burned. Thus 70 lbs. of air passed through each sq. ft. of grate will burn 10 lbs. of coal. Thick fuel beds almost invariably cause clinker. A fuel bed 4 to 5 in. thick kept level will give a reducing atmosphere as well as one 12 in. thick. Soot, the main constituent forming visible smoke is formed in, or near, the fuel bed and not when the hydrocarbons strike the cooling surface of the boiler. If oxygen is supplied in sufficient quantity right at the surface of the fuel bed, soot is not formed. Because of the intermittent feeding of fuel in hand firing it is difficult to provide always a sufficient quantity of oxygen over the fuel bed to burn the volatile matter completely. Probably the best practice is to have an air supply which is just sufficient to meet the requirements as they exist immediately after firing. Graphs are used to show the relation between percentage excess of air and carbon dioxide content for the combustion of Pocahontas, Pittsburgh and Illinois coal. Graphs are used also to show variations in CO_2 content in the furnace gases at intervals of a few minutes during the firing of Pittsburgh, Pocahontas, Anthracite and No. Dakota lignite. Heat losses in operation of a boiler plant are: 35% in the stack gases, 4% by radiation, 4% due to unburned coal falling into the ash pit. 57% of the heat is utilized in making steam. The loss in the stack gases can be largely avoided by reducing the excess air. If furnaces are operated so that the CO_2 content of the flue gases is increased from 6 to 12%, there will be a reduction of 10% in the stack losses and 6 tons of coal will do the same work as 7. The principal causes of large excess of air are holes in the fire, leaky settings and needlessly kept open doors. Firing every 3 minutes is not too often. Frequent poking of the fire causes excessive chimney losses. C. W. P.

PATENTS

13. Refractory brick. CHARLES W. BERRY. U. S. 1,373,854, April 5, 1921. A process of manufacturing refractory material consisting in first mixing the desired proportions of magnesite and bauxite in a raw condition, the mixing water the same, then burning the resultant product at a temperature sufficient to drive off moisture and gas; next, regrinding the calcined product and mixing with water; finally forming same into a suitable shape, and burning such to produce a hard refractory article.

14. Refractory material. EDWARD D. FROHMAN. U. S. 1,372,016, March 22, 1921. A refractory material consisting of a mixture of finely divided dry fire clay, siliceous material and a vegetable compound capable when mingled with water of forming a binder.

15. Arch-brick. WILLIAM SCHUTTLER. U. S. 1,372,320, March 22, 1921. An end arch brick for boiler fire box arch constructions provided on one end with a surface adapted to take against a side sheet and on the other end with a substantially vertically extending convex surface adapted to swinging of the brick on a substantially vertical axis.

16. Tunnel-kiln. GLENN E. NORMAN. U. S. 1,372,773, March 29, 1921. A tunnel-kiln comprizing a longitudinal structure, the walls and dome of which are provided with longitudinal air passages the full length thereof adapted to be heated by the heat affecting the walls of the structure, and an exhaust air directing compartment at one end of the structure into which all of the longitudinal air passages enter. C. M. SAEGER, JR.

Chemistry, Physics and Geology

17. Methods for determining the amount of colloidal material in soils. Preliminary paper. CHARLES J. MOORE, WM. H. FRY AND HOWARD E. MIDDLETON. Bur. Soils, Dept. Agr., Wash. *J. Ind. Eng. Chem.*, **13**, 527–30 (1921).—*Prep. of mat.* After 24 hrs. in settling tanks the supernatant liq. was passed through a Sharples centrifuge and the colloidal mat. in the issuing liq. was sep. by passing through Pasteur-Chamberlain filters and further purified by dialysis and washing.

Properties of ultra-clay. The "ultra-clay" thus obtained was typically colloidal in behavior showing marked Brownian movement, flocculation by electrolytes, and high plasticity and stickiness in the moist condition. Up to a content of 10%, briquettes made with the ultra clay are stronger than those made with Port. cement.

Absorption of ammonia. After calcining at the temps. indicated, the following results were obtained.

Cecil Ultra-Clay

Temperature °C	110	265	374	559	754	1130
Cc. NH_3 absorbed per cc. colloid	110.3	100.8	80.0	74.1	57.5	2.2

Susquehanna Clay Soil

Temperature °C	110	190	265	374	522	673	844	1130
Cc. NH_3 absorbed per cc. soil	27.7	25.3	24.8	19.7	14.9	13.6	7.4	1.4

Calculation of colloidal content. In the light of the above results, the following calculations seem to be justified:

Susquehanna ultra-clay, heated to 110°, absorbed 93.0 cc. NH_3
Susquehanna clay soil, heated to 110°, absorbed 27.7 cc. NH_3
Susquehanna clay soil, heated to 1130°, absorbed 1.4 cc. NH_3

Deducting 1.4 cc. NH_3 absorbed by material, presumably not colloidal, from 27.7 cc. absorbed by the unaltered soil leaves 26.3 cc. absorbed by the colloid of the soil. Therefore, if the pure colloid absorbs 93.0 cc. NH_3 and there is sufficient colloid in the soil to absorb 26.3 cc. NH_3, the colloidal content of the soil must be 28.3 per cent.

Absorption of dyestuffs and calculation of colloidal content. A gram sample is shaken up with 40 cc. of distilled water in a large test tube. A 0.1 *N* sodium oxalate solution is then added until there is a slight excess over the amount required to precipitate the calcium. The tube is corked and placed in an end-over-end shaking machine for 15 min. to insure complete precipitation. The suspension is next treated with a certain small excess of 0.2 per cent *malachite green* solution. The mixture is made up to definite volume (70 cc.) with distilled water, and the tube again placed in the shaking machine for 1 hr. Five cc. of *N* NaCl solution are now added to flocculate the colloidal mat., and the tube is centrifuged in a large mechanical analysis machine until the supernatant liquid is perfectly clear. This liquid is compared in a Duboscq colorimeter with a standard solution of dye to which have been added all of the reagents contained in the other.

Two complete series of Susquehanna clay soil samples were heated as previously described under absorption of ammonia; in fact, the samples for this work were heated in the same furnace and at the same time with the clay pellets in order to be sure the conditions were exactly the same. The dye absorption determinations were then made as above described, with the following results:

Susquehanna Clay Soil

(1 g. of soil, weighed after heating, was used in all determinations)

Weight of Dye Absorbed

Temp. °C	First series 1	First series 2	Second series 1	Second series 2	Average wt.	Aver. loss of sample on heating
110	0.0358	0.0360	0.0352	0.0358	0.0357	0.000
190	0.0344	0.0338	0.0344	0.0342	0.0342	0.003
265	0.0200	0.0200	0.0203	0.0197	0.0200	0.005
374	0.0194	0.0202	0.0204	0.0198	0.0200	0.010
522	0.0	.....	0.0194	0.0196	0.0195	0.055
673	0.0190	0.0185	0.0197	0.0197	0.0192	0.064
844	0.0	.....	0.0105	0.0111	0.0108	0.065
1130	0.0018	0.0015	0.0019	0.0019	0.0018	0.065

Calculation of amount of colloid in Susquehanna clay soil from data obtained by dye absorption method.

Susquehanna ultra-clay, heated to 110°, absorbs 0.1196 g. dye
Susquehanna clay soil, heated to 110°C, absorbs 0.0357 g. dye
Susquehanna clay soil, heated to 1130°C, absorbs 0.0018 g. dye

Deducting the 0.0018 g. dye absorbed by material, presumably not colloidal, from 0.0357 g. dye absorbed by the unaltered soil leaves 0.0339 g. dye absorbed by the colloid of the soil. Therefore, if the pure colloid absorbs 0.1196 g. dye, and there is sufficient colloid in the soil to absorb 0.0339 g. dye, the colloidal content of the soil must be 28.3 per cent. This is exactly the same result as was obtained by the ammonia absorption method.

The results were further checked by mixing pure ultra-clay with weighed portions of soil in which the colloid had been entirely destroyed. Further investigation is promised to determine whether this method of determining colloidal content of clays is generally applicable. ED.

18. A study of the sintering process. K. ENDELL. Tech. Hochschule, Charlottenburg. *Met. u. Erz.*, **18,** No. 8(1921), 10 pp.—After a discussion of the nature of the various processes involved in sintering the author describes the Leitz thermal microscope arranged for studying materials up to 1500°C. The following exp. methods are suggested for ascertaining the nature and mechanism of the sintering process in any given case: (1) Microscopic exam. of the intermediate and final products resulting from calcination at different temps. (2) Microscopic obs. of the sintering process with the thermal microscope. (3) Det. of the amts. of sol. and insol. material after calcination. (4) Det. of the heating curve. ED.

19. Ultramarine blue. SAUVEGEOT. *Rev. prod. chim.*, Apr. (1921); *Tonind. Ztg.*, **45,** 494–5(1921).—The raw materials used in the production of u. blue are kaolin, sulphur, siliceous soil or kieselguhr, soda ash, caustic soda and sodium sulphate. They should be free from impurities especially iron and lime and should contain less than 0.5% Fe_2O_3 since more would produce a dark blue color. Lime acts as a flux and when more than 0.2% is present it causes the product to become sharp and brittle. The kaolin should be white and have a soapy feel. The kaolin should be dehydrated before use. Quartz powder is often used although it is difficult to get into solution and imparts to the product a violet or reddish cast. Kieselguhr may be used to a limited extent together with the quartz. It is desirable since it goes into solution easily but it is too bulky. The S should contain not more than 0.10–0.15% ash and should be free from As. The NaOH should be free from sulphates, chlorides, lime and iron. Rosin and tar are used for reduction purposes. Sawdust and fine coal may also be used. Usually two mixts. are made, one containing no quartz which is unstable and another containing quartz which is stable. Stable blues should be resist. to alum, Al_2O_3 and $C_2H_4O_2$. The following table gives the compositions of numerous shades of blue:

	A	B	C	D	E	F
Raw kaolin	540	325	326	430	524	430
Dried kaolin	...	205	150	...	...	...
Quartz powder	...	...	56	90	...	...
Kieselguhr	...	...	...	...	...	100
NaOH	8	6	6	5	5	3
Cal. soda	538	430	356	384	390	386
Sulphur	268	374	450	440	450	434
Tar	...	...	46	60	50	52
Charcoal	46	60	10	...	...	...
Sawdust	...	...	...	...	...	16

A produces a bright light blue with a greenish tinge, B a light blue, but darker and not as green as A, C a stable blue with a reddish violet tinge, D a stable blue with a reddish tinge, E an unstable blue, F a blue with a violet tinge. The mixts. are ground in a 1400 kg. ball mill for 3 hrs. at 60–70 R.P.M. In the crucible process for making u. blue, crucibles 30 cm. high with 1 cm. walls are used having a capacity of 5 kgs. The crucibles have a cover containing a hole. They are placed in an oven in groups of five. The furnace is fired rapidly for the first 2 hrs. since rapid firing produces a bright color. The crucible becomes red and the sulphur burns through the holes in the tops of the crucibles. The flame remains about 12–15 cm. long for about 7–8 hrs. after which it sinks to 1 cm. showing that the reaction is completed. The furnace is now allowed to cool until the crucible becomes a dull red after which the oven is sealed air tight. A large influx of air at this point would change the blue to white. The proper firing temp. is between 750–800°C. The oven is opened about 6–7 das. after the completion of the burn. Muffle furnaces may be used instead of crucibles and fired in a similar way.

H. G. SCHURECHT

20. Further development of the plastometer and its practical application to research and routine problems. HENRY GREEN. N. J. Zinc Co. *Proc. Am. Soc. Testing Materials*, **20**, II, 451–94(1920).—In the plastometer previously devised by Bingham and Green (*C. A.* **14**, 1047), the container is modified so that the material under test on being forced through the capillary tube at known pressures, displaces air at a rate which is measured by a very sensitive gaseous flow meter. The instrument gives mathematical definition to the character of plastics and is applicable to *degree of plasticity of clays*, particle size, etc. The instrument modifications are described in detail, mathematical detn. of the yield value factor, and graphs and tables of results presented. Bingham in his discussion of the paper shows that it is theoretically possible to measure plasticity by making only 2 measurements of flow through a single capillary. F. A. WERTZ (*C. A.*)

21. Suggestions for calibrating base metal thermocouples by the freezing point method. KIRTLAND MARSH. *Chem. Met. Eng.*, **24**, 1071(1921).—Recommended the use of an iron protective tube in calibrating when molten tin, zinc and aluminum are to be used. The tube is heated to 900 deg. F. and then dipped into a mixt. consisting of one part powdered graphite or ordinary plumbago to two parts water. This produces a protective coating on the tube. When copper is to be used as the calibrating metal a second coating is produced by dipping the graphite coated tube into a mixture of one part by volume slaked lime and one part water. This prevents oxidation of the graphite at the temperature necessary for melting copper. The tube can be cleaned and used repeatedly. The pure metals required can be secured from the Bureau of Standards. H. F. S.

22. Colloid chemistry and its general and industrial applications. F. G. DONNAN AND COMMITTEE. *Rept. Brit. Assoc. Advancement of Science*, **1920**, 1–154A; cf. *C. A.*, **13**, 1784.—The third of this series of excellent reports,

including the following subjects: Soap, ultramicroscopy, soly. of gases in colloidal solns., elec. charge on colloids, imbibition of gels (Tanning), bread making, photography (including collodion), cellulose esters, petroleum, asphalt, varnishes, paints and pigments, *clays and clay products.*

JEROME ALEXANDER (*C. A.*)

23. Ultramicroscopy: Degree of dispersion—measurement with the ultramicroscope. GEORGE KING. *Third Rept. on Colloid Chemistry, British Assoc.*, **1920.**—Discusses concn., size, shape, and internal structure of the dispersed phase, also a solid, liquid and gaseous continuous phase.

JEROME ALEXANDER (*C. A.*)

24. The crystal structure of magnesium oxide. RALPH W. G. WYCKOFF. Geophys. Lab. *Am. J. Sci.*, (5) **1,** 38–52(1921); cf. Davey and Hoffmann, *Phys. Rev.*, **15,** 333(1920).—An attempt is made to get a unique soln. for the structure of MgO as an example of the application of the more general method of studying the structures of crystals which arises from the uses of the theory of space groups. With the aid of X-ray spectrum measurements and Laue photographs it is shown that the "sodium chloride" arrangement is the only simple one that is possible, though there are more complicated groupings that agree equally well with the existing data. R. W. G. W. (*C. A.*)

25. Clays and clay products. A. B. SEARLE. *Third Rept. on Colloid Chemistry, Brit. Assoc.*, **1920.**—A very extensive (40 pp.) and suggestive discussion from the colloid-chemical point of view.

JEROME ALEXANDER (*C. A.*)

26. The electrical charge on colloids. J. A. WILSON. *Third Rept. on Colloid Chemistry, Brit. Assoc.*, **1920.**—A brief discussion.

JEROME ALEXANDER (*C. A.*)

27. Fundamentals of the theory of color measurement. W. OSTWALD. *Z. tech. Physik.*, **1,** 173–5, 261–71(1920); cf. *C. A.* **15,** 739.—A discussion of the theory and use of Oswald's chrometer. D. MACRAE (*C. A.*)

28. Georgia kaolins to be studied. ANON. *Chem. and Met. Eng.*, **24,** 1120(1921).—The Georgia kaolins are to be the subject of a special study to be undertaken by the Bureau of Mines under a coöperative agreement with the Central of Georgia R. R. These white clays of Georgia have been used with some success in ceramic industries, and it is believed that means can be found for a very much more extensive use of them if economical methods can be found for ridding them of impurities. H. F. S.

29. Report of the ceramic division. JOSEPH KEELE. *Summary Report, Can. Dept. Mines,* No. **542,** 102–9(1920).—The occurrences and properties of fire, pottery and brick clays in eastern Ontario are described. **Structural materials in Dundas, Stormont, and Glengary counties, Eastern Ontario.** J. KEELE AND L. H. COLE. *Ibid.*, 114–27.—Results of physical and firing tests of 15 clays and granulometric analyses of 13 sands are tabulated. Pottery clays. MARY E. YOUNG. *Ibid.*, 127–34.—Pottery clays and methods of testing and handling are described. Methods of making glazes, enamels and color decorations are given, also the occurrences of pottery clays in the Canadian provinces. L. W. RIGGS (*C. A.*)

White Ware

30. Investigation of the cause of "blowers" in solid porcelain sanitary ware....and the cure. R. H. MINTON. *The New Jersey Ceramist*, **1**, 27 (1921).—The "blowers" manifest themselves by lifting the glaze like fish scales; or quite often glaze scales are blown entirely free of the body. They vary in size ranging from tiny "ticks" to holes sometimes as large as $^3/_4$" in diameter. There are two forms. In one form small particles of quartz or granitic stones blow off the glaze scales and leave a tiny hole in the center. The second form always shows a black center. The cause of the latter is iron pyrites which give rise to the trouble because of improper methods of firing. The author demonstrated this experimentally. He concludes that "blowers" will always result when pyrite is present in the form of particles $^1/_8$" in diam. or larger and that they will be caused even by minute particles if the firing conditions are improper. Proper firing conditions should be about as follows: 1—Allow sufficient time for water-smoking so that all the ware is properly prepared for oxidation, when that period arrives. 2—When cone 020 is reached, allow time for complete oxidation and continue slow firing up to cone 012. 3—When cone 1 is reached, discontinue firing until the top heat has somewhat settled, and avoid heavy reduction during high fire. 4—A draft gauge should be used and the draft kept under 5 mm.
C. W. PARMELEE

31. Locating most favorable composition of body and glaze. P. H. SWALM. *The New Jersey Ceramist*, **1**, 51(1921).—S. advocates a systematic investigation by each mfgr. of his body and glaze under his own operating conditions in order to discover their limitations as affected by type of kiln, kind of fuel and method of firing. C. W. PARMELEE

32. Porcelain. A. V. BLEININGER. *The New Jersey Ceramist*, **1**, 17 (1921).—A general discussion of different types of porcelain, the changes which take place in the firing of such bodies and a few of the defects of such wares. C. W. PARMELEE

33. Practical points on erection and care of chemical stoneware apparatus. ISMAR GINSBERG. *Chem. Age* (N. Y.), **28**, 252–3(1920).—A description of methods of erecting chem. stoneware app. in the plant and a discussion of points in their care, of compn. of cements, etc., illustrated with diagrams.
ISMAR GINSBERG (*C. A.*)

34. A new colorimeter for white pigments and some results obtained by its use. A. H. PFUND. *Proc. Am. Soc. Testing Materials*, **20**, II, 440–50 (1920); cf. *C. A.* **14**, 1251. (*C. A.*)

35. Luster glazes. ANON. *Keram. Rundschau*, **29**, 197(1921).—The proper temp. to produce lusters with naphthaline is 2 cones lower than the softening temp. of the glaze. Hence a glaze maturing at cone 02a and having a softening point between cones 012–010 will take a luster at cones 014–017. If the temp. is too high the glaze will blister and if too low it will not take a

luster. Paper, sawdust, tar, etc., may be used in the place of naphthaline to produce the desired reducing atmosphere. This method of luster decoration is employed with those glazes containing reducible oxides as copper oxide, etc. H. G. SCHURECHT

36. The production of the red brown salt glaze on stoneware. W. SCHUEN. *Tonind. Ztg.*, **45**, 249–50(1921).—When stoneware is fired the ferric compounds are changed to ferrous imparting to the body a gray color. The color is also gray directly after the salt glaze has been applied since this glaze is transparent. Considerable care is required to change the glaze to the desirable red-brown color. After the glaze has been applied the kiln is allowed to cool until the kiln atmosphere is distinctly oxidizing, after which the fire holes are closed to prevent rapid cooling. This oxidizing soaking period changes the gray ferrous compounds to the red-brown ferric compounds. H. G. SCHURECHT

See also No. 58.

Glass

37. Glass faults, causes and prevention, functions and applications in the glass technique of our day. C. J. STAHL. *Glashütte*, **4**, 819(1920).—"Bad glass" for one purpose may have a desirable property for some other application, as for artistic effects. WM. M. CLARK

38. British scientific glass industry. EDWARD AUINE. *J. Soc. Chem. Ind.*, **40**, 6–7R(1921).—A brief history of the development of the lab. and optical glass industry in the British Empire during the war, directed as an argument for protection against foreign competition. D. E. S. (*C. A.*)

PATENTS

39. Coating glass to prevent accumulation of drops of water. J. H. T. ROBERTS. U. S. 1,369,708, Feb. 22. Accumulation of drops of moisture on glass is prevented by coating the glass with a thin layer of gelatin, agar, casein or similar transparent material. (*C. A.*)

40. Glass-drawing apparatus. JOHN R. SCOHY. U. S. 1,372,044, March 22, 1921. In combination with a glass furnace and a dog-house, a glass segregating apparatus consisting of a deep inverted pot having a central opening in the top thereof, and a sloping exterior surface around the opening and a cylindrical shield having an edge surface conforming to the said sloping surface and adapted to fit the sloping surface and of a length sufficient to reach from the submerged pot to the top of the dog-house, the dog-house being so constructed as to leave unobstructed the said opening of the submerged pot.

41. Glass-grinding machine. EDWARD A. RYON AND ANNA T. RYON. U. S. 1,372,553, March 22, 1921. A glass grinding machine having a horizontally rotatable and longitudinally movable ware holder, gearing therefor, clutch mechanism for connecting the gearing with a source of power having a cone shaped terminal and a power driven cutter having engaged and disengaging mechanism operable by the terminal in conformity with the clutch mechanism.

42. Manufacture of decorative glass, porcelain, or the like. GORO SATO, Sakura, Japan. U. S. 1,372,555, March 22, 1921. A process of producing decorative glass, porcelain and the like, characterized in that thin sheets or patches of the crust or shell of shell-fish are prepared by cleansing the crust or shell, making it thin by grinding, mounting it by means of an adhesive on fibrous paper, crushing it and cutting into pieces or patches, and applying these pieces or patches by means of a suitable binder or adhesive to portions of the glass, porcelain or the like for the purpose specified.

43. Apparatus to be employed in the manufacture of hollow articles of glass. ALEXANDER FERGUSON, England. U. S. 1,371,085, March 8, 1921. In apparatus for manufacturing glassware, a forehearth, or the like, to contain a supply of molten glass, a rotable wheel mounted above the hearth, a series of receptacles arranged around the wheel and having open ends presented at the periphery of the wheel and adapted to enter the glass on the hearth, a plunger working in each receptacle, and means for operating the plungers successively in one direction to draw a charge of molten glass into each receptacle as it enters the molten glass on the forehearth, and means for successively operating the plungers in the opposite direction after the receptacles have the molten glass left to expel the charges from the receptacles, together with means for presenting successive molds to receive the expelled charges.

44. Machine for the automatic and continuous manufacture of glass bottles. GEORGE ORLANDO TAGUE, England. U. S. 1,373,272, March 29, 1921. In a machine for the manufacture of glassware, the combination with a mold charging and forming device and a separate blowing device, of an intermediate opposing gripping members movable up and down, and means for actuating the gripping members having an up and down movement independently of the corresponding movement of the gripping members whereby an article carried by one of the first mentioned devices is engaged and an article at the opposite side is simultaneously disengaged for deposit upon the other of the first mentioned devices.

45. Scleroscope for testing the hardness or strain in glass due to insufficient annealing. CLAUDE M. GARLAND. U. S. 1,370,738, March 8, 1921. In an instrument of the type described, a base, a blackened reflector mounted on the said base, two columns mounted on the base and adjacent to one end of the reflector, a frame slidably mounted on the said columns, a plurality of glass plates carried in the frame and a hood forming a part of the frame and shielding the plates.

46. Method and apparatus for the manufacture of glass. ALEXANDER FERGUSON, England. U. S. 1,371,084, March 8, 1921. In the manufacture of glass, the step of subjecting particles of glassmaking material to a vertical whirl in the presence of gas at smelting heat and leading the resultant viscous mass and the hot gas downward to a refining tank over the surface of the molten glass in which the gas passes.

47. Apparatus for grinding or polishing plate-glass. FREDERIC BARNES WALDRON, Eng. U. S. 1,370,246, March 1, 1921. Apparatus for grinding or polishing plate glass consisting of a series of rectangular tables in contact each with its neighbors forming a continuous support for the plates of glass and slidingly supported on fixed guides, a framework above the series of tables, a series of sets of runners on vertical shafts, bearings for the shafts attached to the framework, means for moving the series of tables continuously from one end to the other of the series of sets of runners, means for removing a table from the moving series of tables after it has left the last set of runners, and means for adding a table to the moving series of tables before the first set of runners, the sets of runners being so spaced apart as to permit of the effective washing away of the abrasive between any two sets using different grades.

48. Apparatus for turning over sheets of glass to facilitate working on both sides of the sheets. GEORGES HENRI LEON DEBAECKER, Netherlands. U. S. 1,371,868, March 15, 1921. A turntable for handling glass sheets and the like, comprizing an invertable frame adapted to receive the sheets, and spaced sets of supporting bars associated with the frame and accommodating the sheet between them, the bars of each set being movable to expose the upper face of the sheet for operations thereon while it rests upon the bars of the other set.

C. M. SAEGER, JR.

Cement, Lime and Plaster

49. Tentative methods for chemical analysis of limestone, lime, and hydrated lime. ANON. *Proc. Am. Soc. Testing Materials*, **20, I**, 626–33(1920).—Weigh out 0.5 g. of the substance and in the case of limestone or hydrated lime ignite in a Pt crucible for 15 min. or more with a blast lamp. Transfer to an evaporating dish, mix to a thin paste with H_2O, add 5–10 cc. of concd. HCl and digest until soln. is complete. Evap. to dryness. Treat the residue with 15–20 cc. HCl (1:1), filter and wash the SiO_2. Repeat the evapn., unite the ppts. of SiO_2, ignite, and weigh. For great accuracy, volatilize the SiO_2 with HF. Ppt. Al and Fe as hydroxides from the filtrate with NH_4OH in the usual way. Reppt., ignite, and weigh as $Fe_2O_3 + Al_2O_3$. Fuse the combined oxides with 3–4 g. of $NaHSO_4$, dissolve in dil. H_2SO_4, evap. to fumes, dil. with H_2O, filter any sepd. SiO_2, ignite, weigh, and add to the value obtained above. Reduce the Fe in the filtrate with H_2S, boil out the excess, and titrate the Fe with $KMnO_4$. Calc. the Al_2O_3 by difference.. Det. Ca in the filtrate from the hydroxide pptn. by pptg. with $(NH_4)_2C_2O_4$ and NH_4OH in the usual way. Ignite to CaO, dissolve in HCl, dil. to 100 cc., add NH_4OH in slight excess, and filter out any $Al(OH)_3$, correcting the value obtained above. Reppt. the Ca as above and either ignite and weigh as CaO, or titrate the CaC_2O_4 with $KMnO_4$. In the latter case, wash the ppt. from the paper with hot H_2O, add 50 cc. dil. H_2SO_4 (1:10), dil. to 150 cc., heat to 85° and titrate to a pink color. Then add the filter paper and complete the titration. Total volatile matter is detd. by igniting a 1-g. sample over the blast lamp. To det. mechanical moisture, weigh a 1-g. sample upon a tared watch glass and

heat at 120° for 2 hrs. Det. SO_3 in a 2-g. sample by dissolving in dil. HCl and pptg. as $BaSO_4$. Det. CO_2 according to the method given in *U. S. Geologic Survey Bulletin*, **422**, whereby a 0.5-g. sample is treated with dil. HCl and the evolved CO_2 is passed though a reflux condenser and then through $CaCl_2$, anhydrous $CuSO_4$, $CaCl_2$, and is finally absorbed by soda lime.

S. G. SIMPSON (*C. A.*)

50. Technical analysis of Portland cement. W. O. ANDREWS. *J. S. African Assoc. Anal. Chem.*, **3**, 3–5(1920).—Details are given of the usual methods for the detn. of SO_3 and insol. matter, SiO_2, Fe_2O_3, Al_2O_3, CaO and MgO. G. W. STRATTON (*C. A.*)

51. Central research laboratory for the cement industry. J. BIED. *Rev ing.*, **28**, 1–7, 61–7(1921).—Brief review of the present state of our knowledge of hydraulic cements and hints on the progress which might result in the cement industry from properly conducted research, to show the importance and advizability of establishing a central research lab. to be supported by the French cement industry. A. P.-C. (*C. A.*)

52. Specifications for the color of gypsum plasters. WARREN E. EMLEY AND CHARLOTTE G. FAXON. *Chem. Met. Eng.*, **24**, 1054(1921).—The methods for measuring color described in detail in Bureau of Standards, *Technologic Papers* **92** and **167** are applied to gypsum plasters and give a very accurate method for classifying these according to color. The requirements suggested for a "white" plaster are, (1) the log. of the diffused reflection for average sunlight shall be numerically less than 0.147, and (2) the ratio of the reflection of blue light (wave length = 436 $\mu\mu$) shall be not less than 0.8. For a "gray" plaster, requirement 1 is changed to read "more than" instead of "less than." Requirement 2 is the same for both white and gray plasters. H. F. S.

53. Lignite brick fuel. ANON. *Rev. Mat. Constr. Trav. Pub.*, No. **141**, 95B (1921).—Lignite brick of average composition C 55%, water 13%, ash 6% and volatile combustibles 26% gives 4800 cal. of heat. It may be used as fuel for all purposes, and is especially of use for heating *lime kilns*. The larger volume of volatile matter continuously removes the CO_2, and thereby accelerates the reaction $CaCO_3 = CaO + CO_2$. LOUIS NAVIAS

54. Fire tests on building columns. S. H. INGBERG, H. K. GRIFFIN, W. C. ROBINSON AND R. E. WILSON. *B. S. Tech. Paper*, **184**.—An investigation of the resistance of cols., loaded and exposed to fire or to fire and water, with a record of characteristic effects, conducted in coöperation with the Associated Factory Mutual Fire Insurance Companies and the National Board of Fire Underwriters, at the Underwriters' Laboratories.

The fire exposure was produced by placing the col. in the chamber of a gas-fired furnace, whose temp. rise was regulated to conform with a predetermined time-temp. relation. Measurements were taken of the temps. of the furnace and test col. and of the deformation of the latter due to the load and heat. The test cols. were designed for a working load of approximately 100,000 lbs. The working load was maintained constant on the col. during the test, the efficiency of the col. or its covering being determined by the length

of time it withstood the combined load and fire exposure. In the fire and water tests, the col. was loaded and exposed to fire for a predetermined period, at the end of which the furnace doors were opened and a hose stream applied to the heated column, the severity of the test being regulated to correspond with the degree of resistance developed by the corresponding type of col. in the regular fire tests. The results of the tests were summarized in terms of hrs., and minutes of fire resistance afforded by the different types of cols. and protections tested. The resistance period is taken as $^2/_3$ of the average time to failure in the fire tests.

The resistance periods thus derived vary from 10 min. for unprotected structural steel cols., to 8 hrs. for similar cols., covered with 4 inch thickness of concrete made with fire resistive aggregates. Filling the reentrant portions or interior of structural steel columns with concrete gave them resistance periods ranging from $^1/_2$ hour to 3 $^1/_2$ hrs., depending on the size and shape of the col. and the concrete aggregates employed. Single-layer protection of plaster on metal lath applied to struct. steel cols., gave a $^3/_4$ hr. resistance, and double layer, with airspace between, 1 $^1/_2$ hrs. Two inch concrete protection on struct. steel gave resistance periods from 1 to 4 hrs., depending on the aggregate. The concrete made with sand and pebbles high in silica (chert and quartz) developed disruptive effects on exposure to fire, which is ascribed (1) to points of abrupt vol. change existing for chert as low as 210°C and for quartz at 573°. (2) To disruption of the pebbles from expulsion of chemically combined occluded water. Concrete made with trap rock, granite sandstone, or hard coal cinder aggregate proved superior to that made with siliceous gravel. The highest resistance obtained with concrete made with dolomitic limestone and calcareous sand. The 4 in. concrete protections developed resistance periods from 2 $^1/_2$ to 8 hrs., variation with the aggregate being similar to that for the 2 in. protections. Hollow clay tile on structural steel cols. gave periods from 1 to 3 hrs., depending on type of clay and method of application. Tile made from semi-fire clay burnt to medium hardness developed greater freedom from cracking and spalling than any other tile tested. Hard burnt semi-fire clay tile evidenced greater effects from fire exposure, and with surface clay and shale tile these disruptive effects were very marked. Little or no difference in resistance was noted as between the 2 and 4 in. thickness of hollow tile, the time to failure being dependent on the area of solid material rather than on the thickness of the air space. Filling the interior with concrete or tile appreciably increased the resistance and stability of the covering, and interior metal ties were found superior to outside wire ties in holding the tile in place. Solid clay brick set on end and edge to form a solid covering about 2 $^1/_2$ in. thick outside of the steel proved somewhat unstable on exposure to fire and developed a resistance period of only 1 hr., while with brick laid flat in the usual manner to form a 4 in. covering, 5 hr. fire resistance was developed. Solid gypsum block, 2 in. in thickness, laid outside of flanges and edges of struct. steel cols. and with space between blocks and flanges filled with gyp. mortar, gyp. blocks

or poured gyp. filling, gave 1 1/2 hr. resistance, and similar coverings made with 4-in. solid blocks gave 3 1.2 hr. resistance, failure being due in all cases to shrinking, checking and disintegration of the blocks which caused them to fall off and expose the steel. Reinforced concrete cols. with 2 in. integral concrete protection, gave 5 hr. resistance made with trap rock aggregate, and 8-hr. resistance made with limestone aggregate. H. F. S.

PATENTS

55. Manufacture of Keene's cement. WILLIAM HOSKINS. U. S. 1,370, 968, March 8, 1921. The method of producing Keene's cement stock which consists in reducing gypsum to a relatively fine state of subdivision passing the subdivided product continuously at a uniform rate through a rotary internally fired kiln, and adding hydrate of lime to the burnt product in amount sufficient to neutralize all acidity.

56. Manufacture of slow-setting cement. FABIO FERRARI, Rome, Italy. U. S. 1,372,015, March 22, 1921. A slow setting calcareous cement free from binary calcium compounds of alumina or iron generally used, which is prepared by converting into slag a raw mixture of the ordinary type used for Portland cement, in which the proportion between the oxide Fe_2O_3 and Al_2O_3 is comprised between 1 and 1.563. C. M. SAEGER, JR.

Enamels

57. The new Meurer enamel spraying process. ANON. *Sprechsaal*, **54**, 490–91(1921).—Meurer with the aid of the Schoop patents developed a spray whereby enamel is molten and sprayed on metals, etc. The spray has attached to it a glass container in which fine ground enamel similar to that used for kiln fired enameling is placed. This powder is drawn out of the container by suction and mixed with compressed air or oxygen which is forced through one jet of the burner. Combustible gases as hydrogen, acetylene or luminating gas are forced out of another jet. With this spray a white enamel as well as others may be applied without a ground coat. Enamels contain potash, soda, lime, fluorspar, cryolite and clay which increase their elasticity. The ground coats used with kiln fired enamels are lacking in these constituents and therefore produce enamels with inferior elasticity. The sprayed enamels are more resistant to blows and sudden temp. changes than the kiln fired enamels which may be partly due to the fact that they can be applied thinner than the kiln fired enamels. In firing enamels in a muffle kiln the carbon, silica, manganese, and phosphorus of the iron are liberated causing reducing conditions. This is especially harmful to reducible oxides such as Sn, Zn, Pb and Cu oxides. By the new method the source of this trouble is avoided. This method may also be used for repairing enamel ware which heretofore has caused many costly delays. In repairing with the spray the combustible gas alone is first used to slowly heat the ware to be repaired. This is done by gradually localizing the heat around the area to be repaired and forcing the molten enamel against the chipped portion. The piece is then allowed to cool slowly by covering the same with an asbestos board.

H. G. SCHURECHT

58. Preparation of glazes and enamels. J. B. SHAW. *New Jersey Ceramist*, **1**, 52(1921).—Red specks are developed in lead glazes byparticles of organic matter such as wood fibre from linings of ball mills, or particles of woody matter from ball clay. The weighing of (large) glaze batches is a useless refinement unless the moisture content of the material is regularly determined and taken into consideration. [The alternative method must be assumed to be proportioning by volume. Abs.] The tempering of glazes should be done during the grinding, and care should be used to proportion the water, plastic clay and tempering agent so as to prevent settling of the heavier constituents. 5 lbs. of ball clay when properly tempered with a suitable flocculating agent is as effective in floating heavy glaze ingredients as 10 lbs. of clay without such flocculating agent. The author is opposed to the practice of preparing large batches of glazes and storing because of the settling of the ingredients and the probability of inadequate stirring before drawing off for use. The importance of thoroughness in the mixing of the ingredients for frits is emphasized. Failure to observe this precaution may occasion a serious loss in the opacity of enamels containing tin oxide or antimony oxide. This applies in some degree to cryolite and other fluorides. One of the essentials in the successful use of antimony oxide in enamels is care in mixing it most thoroughly with the other ingredients before fritting. Little success was attained until it was ground into a ball mill with part of the feldspar of the batch.

During the charging of the frit kiln, there is an appreciable loss of fine dust-like material which is sucked up the stack by the draft. This may be avoided by closing the stack damper before charging, or wetting the charge before introducing it into the furnace. The charge should be spread evenly in the furnace and stirred frequently. This prevents segregation and increases the speed of fusion. The writer has noted the development of specks in white enamels fritted in furnaces using fuel oil. He attributes these to particles of carbon from the fuel oil reducing lead in the frit.

C. W. PARMELEE

Brick and Tile

59. Physical properties of building brick. F. BRICK. *Rev. Mat. Constr. Trav. Pub.*, No. **139**, 49–53(1921).—Data from tests by Bureau of Standards.

LOUIS NAVIAS

60. Straw-paper sheets for blocking up openings in kilns. C. MIRA. *Rev. Mat. Constr. Trav. Pub.*, No. **141**, 84–85B(1921).—Sheets of straw-paper, 6 ft. × 3 ft. may be used to block up entrances to brick kilns. The sheet is impermeable to gases, and is inflammable. By pasting two sheets together along a 6 in. border a wider sheet may be obtained. It is held over the opening by pasting it on to the surrounding brick with flour-paste or clay slip, then by piling brick below and beside the sheet. LOUIS NAVIAS

61. Enamelled brick. G. BRIFFE. *Rev. Mat. Constr. Trav. Pub.*, No. **141**, 87–90B(1921).—A simple layout for a small enamelled brick plant to produce 350,000 brick annually. No details. LOUIS NAVIAS

See also No. 54.

Terra Cotta

62. The manufacture of architectural terra cotta. L. V. *Rev. Mat. Constr. Trav. Pub.*, No. **139,** 55–57B, No. **140,** 70–72(1921); see also previous articles in Nos. **133, 134, 135**(1921).—A history and detailed account of manufacture, taken presumably from American literature. LOUIS NAVIAS

BOOK REVIEWS

63. Technical methods of analysis. ROGER CASTLE GRIFFIN. Pp. 666 and 29 figures. McGraw-Hill Book Co., New York, 1921. This book is a laboratory manual, giving explicit directions for making chemical analyses. The methods selected are those which have given general satisfaction in commercial work. Assuming that the reader has had some experience as an analyst, the directions given can be easily followed. Besides the analytical directions, methods for physical testing are also given when these are necessary to establish the quality of the material. No attempt is made to give any theories or explanations. The scope of the work is very extended, including methods for the analysis of almost everything, organic or inorganic, which is an ordinary article of commerce. WARREN E. EMLEY

ACTIVITIES OF THE SOCIETY

New Members Received During June, July and August

Resident Associate

Aurien, George, 4070 N. Main St., St.Louis, Mo., Superintendent, Mississippi Glass Co.

Bloomfield, Howard W., Metuchen, N. J., Secretary, Treasurer, and Manager, New Jersey Clay Products Co.

Carspecken, H. L., Morgantown, W. Va., Manager, Mississippi Glass Co.

Douglas, Ralph J., Cincinnati, Ohio, Pottery Manager, The John Douglas Co.

Duhart, A. L., Port Allegany, Pa., Assistant Manager, Mississippi Glass Co.

Duval, A. M., 901 North Forest Ave., Brazil, Ind., Salesman, Manufacturers Equipment Co., Dayton, Ohio.

Farris, P. C., 9 W. Park St., Brazil, Ind., Superintendent, Hydraulic Press Brick Co.

Ford, George D., 104 Woodlawn Ave., Zanesville, Ohio, Ceramic Engineer, Mosaic Tile Co.

Franzen, Nick., Port Allegany, Pa., Manager, Mississippi Glass Co.

Grant, Frederic J., 134 Woodlawn Ave., Zanesville, Ohio, Mosaic Tile Co.

Greene, R. J., 156 W. Indiana Ave., Sebring, Ohio, Foreman, Gem Clay Forming Co.

Gutmann, Paul F., 4248 Blaine Ave., St. Louis, Mo., Assistant Superintendent, Mississippi Glass Co.

Hahn, Carl A., 2138 Blendon Place, St.Louis, Mo., Assistant Engineer, Parker Russell Mining and Mfg. Co.

Hall, F. P., 1758 Columbia Rd., Washington, D. C., Bureau of Standards.

Henry, Kenneth M., San Francisco, Cal., Illinois Pacific Glass Co.

Herrold, R. P., 955 Brighton Blvd., Zanesville, Ohio, Mosaic Tile Co.

Ichijo, Mokiji, c/o J. H. Ohyama, Woolworth Bldg., New York City.

Klaesius, Paul K., 3350 Scotten Ave., Detroit, Mich., Factory Superintendent, Wolverine Porcelain Enameling Co.

Koering, E. W., Crystal Ave., Vineland, N. J., Kimble Glass Co.

Lawler, John J., 839 Thomas Ave., Forest Park, Ill., Jas. H. Rhodes & Co.

Lord, N. W., Jr., 338 W. 8th Ave., Columbus Ohio, Ohio State University.

Maley, Wm. V., 315 W. Maryland Ave., Sebring, Ohio, Limoges China Co.

Miller, J. Walter, 634 Forest Ave., Zanesville, Ohio, Mosaic Tile Co.

Mills, Geo. P., 908 Chestnut St., Philadelphia, Pa., Electric Furnace Construction Co.

Montgomery, J. C., Sebring, Ohio, Superintendent, Limoges China Co.,

Morley, S. I., 246 East Ohio Ave., Sebring, Ohio, Sales Manager, Sebring Pottery Co.

Ramsdell, Lewis, S., 29 West St., Worcester, Mass., Norton Co.

Rhead, John, Hotel Columbus, Columbus, Ohio, General Manager, Sanitary Earthenware Specialty Co.

Robison, David V., 104 Woodlawn Ave., Zanesville, Ohio, Mosaic Tile Co.

Saunders, Lewis E., 262 Salisbury St., Worcester, Mass., Norton Co.

Schwier, Carl, 295 E. 4th St., Mansfield, Ohio, Mansfield Vitreous Enameling Co.

Scott, R. N., Old Hickory Clay & Talc Co., Paducah, Ky., Secretary-Treasurer.

Smith, C. B., 1010 Hancock St., Saginaw, W. S., Mich., Assistant Superintendent National Plate Glass Co.

Underwood, C. A., Valley, Wash., Superintendent, American Refractories Co.

Vieweg, George B., 494 Grand St., Morgantown, W. Va., Assistant Manager, Mississippi Glass Co.

White, Richard P., 121 S. Menard Ave., Chicago, Ill., Secretary-Treasurer, Union Stoneware Co.

Foreign Associate

Jacobsen, Carl, Malmogade 7, Copenhagen, Denmark, University of Copenhagen.

Knudsen, Rolf, Borgestad, Norway.

Lax, Thomas, Hunslet, Leeds, Yorkshire, England, Director, Lax & Shaw, Ltd.

Naganuma, Hikosaburo, Kamoike Works, Electric Railroad Co., Kagoshima, Japan.

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Moore & Munger, 29 Broadway, New York City.

Niles Fire Brick Co., 165 E. Park Ave., Niles, Ohio.

Parker-Russell Mining & Mfg. Co., 603 Laclede Gas Bldg., St. Louis, Mo.

The Product Sales Co., 206 Water St., Baltimore, Md.

Reading Fire Brick Works, Reading, Pa.

Stockton Fire Brick Co., 915 Rialto Bldg., San Francisco, Cal.

NECROLOGY

Silas Carl Linbarger, for the past six years ceramic engineer of The Carborundum Company, Niagara Falls, N. Y., died at his home in that city Saturday, September 10th.

Mr. Linbarger was born at San Jose, Ill., September 21, 1892, was graduated from the Champaign (Illinois) High School and the University of Illinois,

class of 1915. After a short time as instructor at the University, he entered the employ of The Carborundum Company, where, on the death of Mr. L. B. Coulter, he was promoted to the responsible position of Ceramic Engineer, which position he filled until he succumbed to the ravages of a disease against which he has gamely fought for several years.

Although a young man, Mr. Linbarger carried responsibilities in his line of work usually borne by men of twice his years. In the field of refractories and abrasives he was an authority. His knowledge of grinding operations was a most comprehensive one.

Among his patents was one covering a crucible of graphite, clay and silicon carbide, used for melting metals. The crucible, now a commercial article, has proved to be more efficient and of longer life than the old-fashioned kind made of graphite and clay. This new crucible is not to be confused with that made of firesand, graphite and clay, of earlier origin.

Under Mr. Linbarger's direction there was also developed, the clay and silicon carbide mixture for making such articles as saggers. These known as "Carborundum Saggers" are used by ceramists engaged in the art of making both heavy and light porcelain ware, such as sanitary ware, spark plugs, etc. The greater strength of such saggers, coupled with their high thermal conductivity, make them extremely efficient and are a great credit to their inventor.

These developments alone would have been sufficient for one of his years, but they were not the whole of his work. Improved grinding wheels, both of silicon carbide and aluminous abrasives, refractory articles of special shapes for various industries, including electric furnace linings, gas retort linings and the like, have been the product of his mind, as director of the experimental work along such lines.

Mr. Linbarger was one of the younger trained ceramic men who were endeavoring to build up the American Ceramic Society, and he had been a member of several committees. The respect of his fellows is evidenced by his election as President of the N. Y. State Section of the society.

He leaves a widow Helen Garwood Linbarger and his mother Mrs. Rose Linbarger, living at Niagara Falls.

Services were held at St. Mary's Roman Catholic Church, Niagara Falls, Monday, September 12th, at which was gathered a large delegation from The Carborundum Company, the American Chemical Society and the American Ceramic Society, together with many personal friends. Interment took place at San Jose, Ill., his birthplace.

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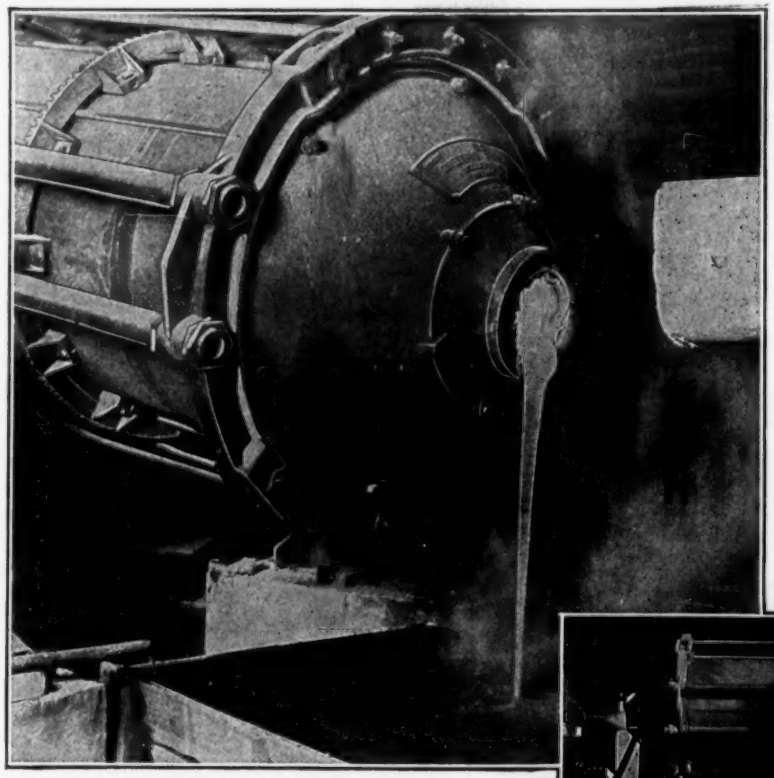

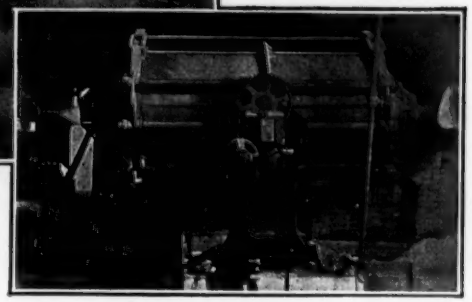

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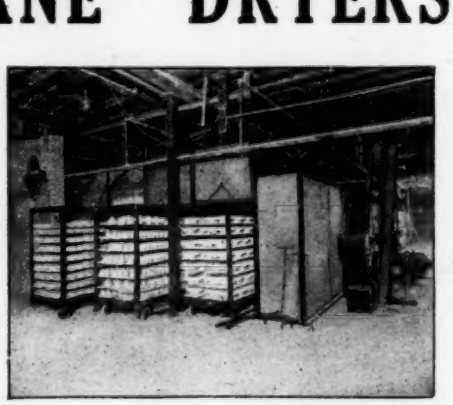

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THE HADFIELD PENFIELD STEEL CO.
BUILT RIGHT RUN RIGHT
BUCYRUS OHIO

CLAY PLANT EQUIPMENT

We build every machine and appliance required for making various Clay Products. Correspondence solicited. We also build Rotary Driers, Cement Mchy., Fuel Oil Engines (Diesel Type), Gasoline Locomotives, Ship Deck Equipment, etc.

The Hadfield-Penfield Steel Co., Bucyrus, Ohio.

Formerly The American Clay Mchy. Co.

1-22

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Highest Grade Crude Rock Feldspar

Pottery and Dental Trades
Derry Spar ground by Dominion Feldspar Corporation
QUARTZ, ELECTRICAL MICA, PHOSPHATE, ETC.

O'BRIEN & FOWLER
511 UNION BANK BUILDING

OTTAWA CANADA

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GRAND VIEW FIRE CLAY MINES

Miners of Highest Grade

FURNACE CLAY
RAW POT, BLOCK FORM
BURNT POT, BLOCK FORM
CRUDE GROUND
BURNT GROUND and
SPECIAL PREPARED
CLAYS OF ALL KINDS

PLASTIC CHELTENHAM
MISSOURI FIRE CLAY

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SAINT LOUIS, MISSOURI

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Quality *Uniformity* *Experience*

Edgar QUALITY *Clays*

REALLY washed—Highest percentage clay substance

Brands	*Produced by*
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Edgar Georgia Paper Clay and Kaolin	*Edgar Brothers Co.*
Lake County Florida Clay	*Lake County Clay Co.*

One Management—Office, Metuchen, N. J.

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—as manufactured by the

GENERAL CERAMICS COMPANY

is all that the name implies.

There is no better Stoneware made for

QUALITY—SERVICE—VALUE

Write for descriptive bulletins

GENERAL CERAMICS COMPANY

50 Church Street **New York City**

Leading American Manufacturers of Acid-Proof Chemical Stoneware

ENGLISH
AND
DOMESTIC

CLAYS
FOR
ALL
CERAMIC
PURPOSES

—PMCCO—
MEANS SERVICE, QUALITY AND PRICE

PAPER MAKERS CHEMICAL CO. EASTON, PA.

9-21

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CHEMICALS

SELENITE of SODIUM

ARTIFICIAL CRYOLITE
for white and opalescent glass

SODIUM SILICO FLUORIDE

UNDERGLAZE COLORS
for high temperatures

POTTERY GLAZES & ENAMELS

The Vitro Mfg. Co. Pittsburgh, Pa.

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Established 1869

Antimony Oxide
Cadmium Sulphides
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Cobalt Oxides
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Powder Blue
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GREAT FLORIDA DEPOSITS

Are owned by us. The largest and most unique plant of its kind in the world is producing Zircon of various grades, for use in Super-Refractories, Electrical Porcelains, Spark Plug Cores, Glazes and Enamels.

Zircon is used to advantage in place of Sillimanite, Fused Silica, Alumina and Kaolin.

Zircon needs no calcining, has permanent volume and our best grade fuses above 4000° F.

Send for Interesting booklet.

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MINERS AND MANUFACTURERS

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New York City Office, 94 Fulton Street

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Electrical Porcelain, General Ware, Sanitary Ware, Tile, Brick and other clay Products are dried by "Proctor" Dryers with results superior in quality, efficiency and economy. Let us send you our catalogue.

PROCTOR & SCHWARTZ, Inc. Philadelphia, Pa.

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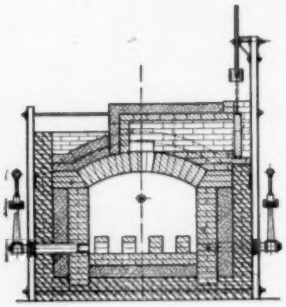
Utilizing Clark patented principle of intermittent and direct firing (The Surface Combustion Co.,—Sole Licensee)

HAVE PROVEN MOST EFFICIENT



Direct fired gas	**1.0c**
Semi-muffle gas	1.4
Electric direct	1.4
Oil fired	1.5
Full muffle gas	1.6
Coal fired muffle	1.7

The above table shows the comparative costs per hour, per cu. ft., of oven space heated, of the various types of enameling furnaces now in use.

Write now for full details and engineering data.

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THE SURFACE COMBUSTION CO.
Engineers & Manufacturers of Industrial Furnaces for all purposes

Main Offices and Works:
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Highest Grade Domestic

BALL CLAYS *PLASTIC SAGGER CLAYS* *WAD CLAYS*

THE JOHNSON-PORTER CLAY CO.
McKenzie, Tenn.

8-22

A WORD FROM THE MEMBERSHIP COMMITTEE.

EVERY MAN in the Ceramic field owes it to himself and to the industry to be a member of THE AMERICAN CERAMIC SOCIETY.

The growth of the Society shows its increasing importance. Membership means influence and prestige for every man affiliated.

The circulation of the "Journal" is keeping pace with the growth of the Society and the advertising is increasing as well. Every membership received means greater possibilities in its work.

For full information address—

FRANK H. RIDDLE, Chairman
Membership Committee
JEFFREY-DE WITT CO.,
Detroit, Michigan

THE DOMINION FELDSPAR CORPORATION

ROCHESTER, N. Y.

Wish to announce to the High Class Pottery and Insulator trade of America that they are producing a

Super Quality Canadian Ground Feldspar

Known as "Derry" SPAR

This spar is now being supplied to some of the largest and most critical concerns in the country, who have placed their entire business with us, and is pronounced by them to be

The Finest Spar obtainable on the Continent. Quality and uniformity guaranteed the same in every car shipped. Continuity of Supply assured for years to come.

The capacity of our mills is already two-thirds booked and we are in a position to take on a few more customers who are desirous of improving their product to the highest possible standard, and at the same time assuring themselves of a continuous supply of uniform quality.

"Derry" Feldspar will correct all your troubles

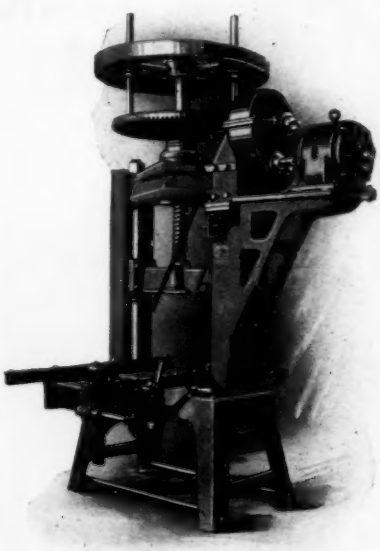
Sample, carloads or less, will be submitted to intending purchasers.

All correspondence to

THE DOMINION FELDSPAR CORPORATION

Rochester, N. Y.

NOTE: *This spar is produced by O'Brien & Fowler at their celebrated "Derry" Mine at Buckingham, Quebec, and is milled and sold in the United States exclusively by the above Corporation.*



Pat'd July 10, 1917

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ELECTRIC
SEGGAR PRESS

Simple
Durable
Efficient
Inexpensive

Write for catalog.

MUELLER MACHINE CO., Inc.

Trenton, N. J.

Five Hundred Dollars Escaped
Through this Brick Crown

"Last year", said Sherman, "five hundred dollars in real money escaped through the crown of this brick kiln by excessive heat radiation.

But this year I am going to turn that five hundred right back into our treasury, and perhaps more, too. I have had the entire kiln insulated with SIL-O-CEL brick. Actually encloaked in a heat impenetrable covering that will prevent the loss of from 60% to 70% of the heat which ordinarily escapes unused through radiation".

Interesting data on the savings that can be accomplished through SIL-O-CEL insulation of Ceramic Kilns are contained in Bulletin A-5A. Write our nearest office for a copy.

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NEW YORK - 11 BROADWAY DETROIT - BOOK BUILDING DENVER - SYMES BUILDING
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NEW ORLEANS - WHITNEY CENTRAL BANK BUILDING

Supplied in Brick, Blocks, Powder and Cement

SIL-O-CEL

PREVENTS HEAT PENETRATION

TRADE MARK REGISTERED U.S. PATENT OFFICE

4 ft. style "B" Dry Pan

We are engineers to the clay-worker

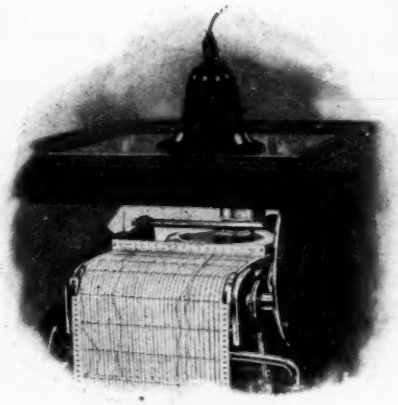
We have been in business since 1879.

You are invited to benefit by our extensive service. Our catalog will interest you. Write for it.

The Crossley Machine Company

Trenton, N. J.

1-22



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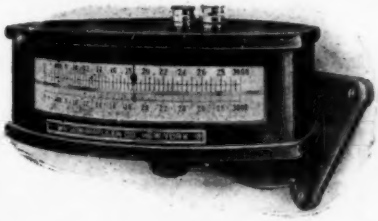

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TRUEST
Combination
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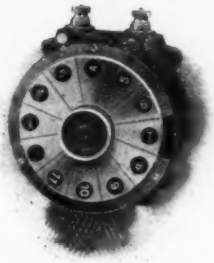
Accuracy
Durability
Robustness
Convenience



PYROMETERS for Production or Research

Wilson-Maeulen Co., Inc. 386 Concord Ave., New York

5-22

COAL, COKE, GAS, OIL FIRED

ENAMELING MUFFLES
SMELTERS
INDUSTRIAL FURNACES

DESIGNERS AND BUILDERS
HIGH GRADE FIRE BRICK, SPECIAL TILE
SILICA BRICK AND TILE, ETC.

YOUR INQUIRIES WILL RECEIVE PROMPT ATTENTION

THE PARKER RUSSELL
MINING AND MANUFACTURING CO.

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If you want pyrometer protection tube satisfaction
USE
Montgomery Hard Porcelain Pyrometer Tubes
All Sizes and Lengths for either Platinum or Base Metal Couples
The Best Liked and Most Largely Used Protection Tubes on the Market today
If the manufacturer of your pyrometer equipment cannot supply you, write us direct.
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BRICK MAKING MACHINERY
OF THE STRONGER AND BETTER CLASS
We specialize on Dies and Augers and to their adaptation to individual requirements. Automatic Cutters up to 12000 bricks per hour Capacity.
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4-22

SOLE IMPORTERS OF
KRYOLITH GENUINE **GREENLAND**
FOR THE GLASS AND ENAMEL TRADES
MANUFACTURERS OF
NATRONA HYDRATE and OXIDE
FOR THE GLASS, ENAMEL AND PORCELAIN TRADES
ALUMINA
And Other INDUSTRIAL CHEMICALS
Pennsylvania Salt Manufacturing Co.
MAIN OFFICES: PHILADELPHIA
615 UNION ARCADE BLDG. PITTSBURGH, PA.
1-22

Do You Want Taxes Reduced?

Foolish question—of course you do!

Well, you can begin right now in your plant.

Have you any idea of the taxes you are paying in the form of lost time, extra fuel and spoiled product through not being able to know and control the temperature in your kilns.

You can reduce these taxes by using pyrometers.

ENGELHARD PYROMETERS

have reduced the taxes levied by guess work methods in many plants in your line.

They are built with the needs of your plant in mind and so are

ACCURATE
STRONG
DEPENDABLE

And their users will tell you that their upkeep expense is so low that they are the economical pyrometer to buy.

Whenever you think of pyrometers remember that

Engelhard Pyrometers Are Good Pyrometers To Standardize On.

Charles Engelhard, Inc.

30 Church Street **New York City**

This Journal Is Exceptional

in that no increase in the advertising rates has been made since the beginning of the Journal two and one-half years ago, although in that time a number of substantial increases have been made in the cost of production, such as the cost of paper, printing, distribution, etc.

At the present time, however, it looks as though costs of production would at least hold steady for some little time ahead and the Board of Trustees and Committee on Publications have jointly decided upon a new schedule of advertising rates which shows increases only sufficient to make the advertising pages bear a fair proportionate cost of the Journal.

Business men who regularly advertise will recognize in these rates a fair adjustment and a good return for the money.

The new schedule of rates as now effective for new space and which will gradually be applied to space already contracted for, from time to time as old contracts expire, are shown in the following tabulation:

ADVERTISING RATES:

Space	*One Insertion*	*Three Insertions*	*Six Insertions*	*Twelve Insertions*
Eighth page	$ 9.75	$ 9.00	$ 8.25	$ 7.50
Quarter page	18.00	16.50	15.00	13.50
Half page	33.00	30.00	27.00	24.00
Full page	60.00	54.00	48.00	40.00

Preferred space	Back cover	List plus 25%
	Inside back cover	List plus 20%
	Opposite inside back cover	List plus 20%
	First page after reading	List plus 20%

EQUIPMENT

¶ The PEMCO Organization will design your Porcelain Enameling Plant and furnish and install for you—ready to do business—a complete and efficient Enameling Equipment at a fixed price.

ENAMELS

¶ PEMCO will furnish you Porcelain Enamels for your particular purpose. PEMCO Enamels are attested superior to any other make. PEMCO Enamels are dependable and run absolutely uniform. PEMCO Enamels sink into and fuse with the base metal. All colors finish in a brilliant high gloss. PEMCO is the largest Producer of Vitreous Enamels.

SERVICE

¶ PEMCO Service in connection with PEMCO Enamels is the feature which made the name "PEMCO" famous. PEMCO has the long experience which helps our friends to do good Porcelain Enameling economically right from the Start.

PEMCO puts your Plant in operation, shows you how to do the work right and keeps a general supervision over your Enameling Department to insure maximum production.

"PEMCO IS RELIABLE"

The Porcelain Enamel & Manufacturing Co.

BALTIMORE, MD.

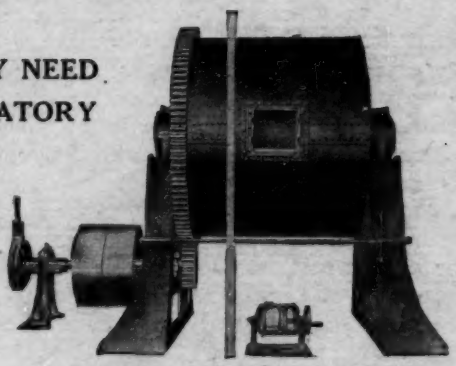
6-22

BALL OR PEBBLE MILLS

WHEN YOU REQUIRE ONE BE SURE IT'S AN

ABBÉ ENGINEERING CO. MILL

A SIZE FOR EVERY NEED
FOR THE LABORATORY
OR PLANT.



ABBÉ PEBBLE MILL (Patented)

Our patented manhole frame is a feature which will undoubtedly appeal to you.

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ABBÉ ENGINEERING COMPANY

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Cort. 54-55-56

HUDSON TERMINAL BUILDING
50 Church Street, New York.

Works
Brooklyn, N. Y.

1-22